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(73) Proprietor: HONDA GIKEN KOGYO KABUSHIKI  
KAISHA  
Minato-ku Tokyo 107 (JP)

(72) Inventors:

- Hosoi, Takashi  
Wako-shi, Saitama-ken 351-01 (JP)
- Hiyama, Satoshi  
Wako-shi, Saitama-ken 351-01 (JP)
- Shinotuka, Sukeyuki  
Wako-shi, Saitama-ken 351-01 (JP)
- Doi, Mizuho  
Wako-shi, Saitama-ken 351-01 (JP)

- Yamakawa, Hiroshi  
Wako-shi, Saitama-ken 351-01 (JP)
- Kuriyama, Naraki  
Wako-shi, Saitama-ken 351-01 (JP)
- Nishio, Tomoyuki  
Wako-shi, Saitama-ken 351-01 (JP)
- Inaba, Atsushi  
Wako-shi, Saitama-ken 351-01 (JP)
- Fueki, Nobuhiro  
Wako-shi, Saitama-ken 351-01 (JP)

(74) Representative: Tomlinson, Kerry John et al  
Frank B. Dehn & Co.,  
European Patent Attorneys,  
179 Queen Victoria Street  
London EC4V 4EL (GB)

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## Description

[0001] The present invention relates to an acceleration sensor for detecting acceleration acting on the sensor body, and, more particularly, to an acceleration sensor for detecting acceleration in the form of changes in the temperature distribution of gas in a closed space.

[0002] Disclosed in Published Unexamined Patent Application No. JP 3-176669 is an acceleration sensor in which the equilibrium of the temperature distribution is formed by heating a gas enclosed in a space closed in a case, and the phenomenon in which the temperature distribution is changed while an air flow is generated by the action of acceleration is detected as a change in the resistance of a resistance temperature sensor disposed within the case.

[0003] In the above conventional acceleration sensor, a thin-film-resistor temperature sensor serving also as a heater is disposed in a resin case, and heated by applying current thereto. Resistance values are previously detected for the heated thin-film-resistor temperature sensor at various temperatures.

[0004] When acceleration acts on the acceleration sensor, an air flow is generated in the case. The generated air flow takes heat from the thin-film-resistor temperature sensor, thereby reducing its temperature so that the resistance of the thin-film-resistor temperature sensor is changed.

[0005] Because the change in the resistance of the thin-film-resistor temperature sensor corresponds to the acceleration acting on the acceleration sensor, the acceleration is detected by converting the resistance of the thin-film-resistor temperature sensor to an electric signal.

[0006] The conventional acceleration sensor has, however, a problem that, although it can detect the absolute value of acceleration, it cannot detect the direction in which acceleration acts because it uses the same element to act as both the heater for the gas in the case and the temperature-sensing element which detects the temperature change due to the action of acceleration.

[0007] In addition, the conventional acceleration sensor has a problem that, because the thin-film-resistor temperature sensor for the heater serves as both a heater and a temperature-sensing element, aging from deterioration for the temperature is caused in the thin-film-resistor heating-type temperature sensor if the generated temperature is high, leading to variations in heat generation and reduced sensitivity to temperature so that the sensor cannot accurately detect acceleration.

[0008] Moreover, the conventional acceleration sensor has a relatively bulky size for the closed space, which results in a degraded response to the temperature change by the air flow. Reduction of the size of the acceleration sensor is limited by its structure.

[0009] Furthermore, while the accuracy of acceleration detection depends on the positional accuracy of the thin-film-resistor heating-type temperature sensor, the conventional acceleration sensor has a structure in which the thin-film-resistor heating-type temperature sensor is directly installed on the case, which makes it difficult to accurately position the thin-film resistor heating-type temperature sensor.

[0010] DE-A-4243978 discloses an acceleration sensor which uses two or more resistance elements to detect the flow of a gas in a sensor housing.

[0011] The present invention provides a sensor including at least one temperature-sensing resistor means disposed, in use, within a closed space, gas in the closed space being heated, and wherein, when an acceleration acts on the sensor, the resistance of the resistor means changes due to flow of the gas over the resistor mean, characterised in that the sensor comprises a semiconductor or insulating substrate having a cavity therein, and a projection means of insulating material extending in the space at least part way across the cavity, the resistor means being integrally formed on the projection means.

[0012] The invention may provide a very small acceleration sensor which is constructed by etching a semiconductor or insulating substrate using a photoengraving process in the semiconductor manufacturing process. Preferably, two sensor cases each with a cavity therein are joined together to form a closed space, with a bridge being formed at the center of one of the sensor cases at the time the cavity is formed, on which is integrally placed a temperature-sensing resistor element and a heater through the photoengraving process, the element accurately detecting imbalance in the temperature distribution generated in the closed space by acceleration acting on the sensor case as a change in resistance of the temperature-sensing resistor element.

[0013] Preferably, the acceleration sensor can accurately detect the absolute value of acceleration acting on the sensor case in any one, two or three-dimensional direction and the direction of action, for example by arranging a pair of temperature-sensing resistor elements in the sensor case in one-dimensional (X axis), two-dimensional (X and Y axes) or three-dimensional (X, Y, and Z axes) axial directions.

[0014] As described, because the acceleration sensor is constructed by using the photoengraving process in the semiconductor manufacturing process, resistance values of the temperature-sensing resistor element and the heater and their positioning in the sensor case can be attained with high accuracy.

[0015] Therefore, the present invention may provide an acceleration sensor which eliminates problems inherent to the conventional acceleration sensor of poor response to the detection of acceleration due to limitations in the reduction

of the size, poor accuracy of acceleration detection due to an inability to accurately position the temperature-sensing resistor element and the heater, time consumed for selecting the resistance for the temperature-sensing resistor element and the heater, and the occurrence of waste parts, and which is very small in size, has excellent accuracy in acceleration detection, and is suitable for mass production.

**[0016]** Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a cross-sectional view of a first embodiment of the acceleration sensor according to the present invention;  
FIG. 2 is a plan view of a lower sensor case of the first embodiment of the acceleration sensor according to the present invention;

FIG. 3 is a cross-sectional view of a second embodiment of the acceleration sensor according to the present invention;

FIG. 4 is a plan view of a lower sensor case of the second embodiment of the acceleration sensor according to the present invention;

FIG. 5 is the arrangement of a detection circuit of the acceleration sensor of FIG. 4;

FIG. 6 is a plan view of a lower sensor case of a third embodiment of the acceleration sensor according to the present invention;

FIGS. 7 and 8 are the arrangement of a fourth embodiment of the acceleration sensor according to the present invention;

FIG. 9 is a functional block diagram for the detection of acceleration by using the acceleration sensor of FIGS. 7 and 8;

FIGS. 10 and 11 are the arrangement of a fifth embodiment of the acceleration sensor according to the present invention;

FIG. 12 is a functional block diagram for the detection of acceleration by using the acceleration sensor of FIGS. 10 and 11;

FIG. 13 is another embodiment of the acceleration correction means in FIG. 12;

FIGS. 14 and 15 are the arrangement of a sixth embodiment of the acceleration sensor according to the present invention;

FIG. 16 is a bridge circuit diagram in the acceleration sensor in FIGS. 14 and 15;

FIGS. 17 and 18 are the arrangement of a seventh embodiment of the acceleration sensor according to the present invention;

FIGS. 19 and 20 are the arrangement of an eighth embodiment of the acceleration sensor according to the present invention;

FIG. 21 is the arrangement of essential components of a ninth embodiment of the acceleration sensor according to the present invention;

FIGS. 22a and 22b show perspective and top plan views, respectively, of the appearance of the acceleration sensor shown in FIG. 21;

FIG. 23 is a diagram illustrating the operation of the acceleration sensor shown in FIG. 21; and

FIGS. 24 - 27 are diagrams of the acceleration detection circuits of the acceleration sensor shown in FIG. 21.

**[0017]** FIG. 1 is a cross-sectional view of a first embodiment of the acceleration sensor according to the present invention, and FIG. 2 is a plan view of a lower sensor case of the first embodiment of the acceleration sensor according to the present invention. They show the basic arrangement of the acceleration sensor according to the present invention.

**[0018]** Referring to FIGS. 1 and 2, an acceleration sensor 1 comprises a lower sensor case 2 formed therein with a cavity 4 and a bridge 5 by, for example, etching a semiconductor substrate with a fine-processing technique in the semiconductor manufacturing process, and an upper sensor case 3 formed therein with a cavity 7 by etching a semiconductor substrate, a closed space 8 being formed by joining the cases so that the cavities 4 and 7 abut each other.

**[0019]** The closed space 8 is filled with an inert gas with a low heat transfer coefficient such as nitrogen or argon under pressure.

**[0020]** In addition, metal such as platinum is vapor-deposited on the surface of the bridge 5 of the lower sensor case 2, and etched to form a heat-type temperature-sensing resistor element 6 with a desired pattern.

**[0021]** The bridge 5 is formed to bridge the center of the cavity 4 of the lower sensor case 2. Etching and vapor evaporation are controlled to accurately position the heat-type temperature-sensing resistor element 6 at the center of the closed space 8 when the acceleration sensor 1 is constructed.

**[0022]** An electrode 9 formed by the same material as the heat-type temperature-sensing resistor element 6 is provided on the extension of the heat-type temperature-sensing resistor element 6 to electrically determine changes in the resistance of the heat-type temperature-sensing resistor element 6 which is caused by detecting the supply from

an external power supply and the action of acceleration (G).

[0023] For the acceleration sensor 1 thus constructed, a thermal equilibrium state with a steep temperature gradient is previously attained by heating the heat-type temperature-sensing resistor element 6 with the supply from the external power supply through the electrode 9.

[0024] In the thermal equilibrium state, when acceleration (G) acts on the acceleration sensor 1 in the direction perpendicular to the longitudinal direction of the heat-type temperature-sensing resistor element 6, a gas flow corresponding to the absolute value of the acceleration (G) and its direction of action is generated in the closed space 8, which makes the temperature distribution in the closed space 8 unbalanced and lowers the surface temperature of the heat-type temperature-sensing resistor element 6.

[0025] Lowering of the surface temperature changes the resistance of the heat-type temperature-sensing resistor element 6 so that the absolute value of the acceleration (G) acting on the acceleration sensor 1 can be detected by electrically detecting the change in resistance.

[0026] As described above, in the acceleration sensor 1 according to the present invention, the sensor cases 2 and 3, the bridge 5, and the heat-type temperature-sensing resistor element 6 are formed by etching or vacuum evaporation with a fine-processing technique in the semiconductor manufacturing process so that a very small acceleration sensor several millimeters square can be constructed and so that the acceleration can be detected with a quick response and high accuracy.

[0027] Although the first embodiment has the sensor case constructed of a semiconductor substrate, it may also be constructed of an insulating substrate such as glass or ceramic.

[0028] In addition, the upper sensor case 3 is not limited to the semiconductor or insulating substrate, but may be constructed of glass or metal.

[0029] Furthermore, the sensor may comprise merely the lower sensor case 2 and the heat-type temperature-sensing resistor element 6, without the need necessarily for the upper sensor case 3. In this case, the sensor may then lie, in use, in a space in a body on which the sensor is mounted. For example, if the sensor is to measure the acceleration of a body to which it is attached, the sensor could be mounted on a plate bolted over a small recess in the body such that the sensor lies in the recess. This may be true of later embodiments also.

[0030] In the following embodiments, it is also assumed that the sensor case, the bridge, the heater, the temperature-sensing resistor element, and the heat-type temperature-sensing resistor element are formed by using fine-processing technology of the semiconductor manufacturing process.

[0031] For example, a photoengraving process for making substrate 2 may comprise the steps of depositing an oxide coating such as SiN on a silicon substrate, depositing platinum or another suitable metal on the SiN, etching the metal to form resistor element patterns, possibly depositing a further oxide coating such as again SiN over the metal patterns, and etching the silicon substrate beneath the oxide coating and metal to make a cavity 4 with a bridge (5) thereabove of the oxide coating with the metal etched patterns thereon. The substrate 3 may also be etched to produce the cavity 7 therein. Both substrates may be placed in an oven and joined with thermosetting resin. The oven may be filled with for example Ar gas, which may be under pressure, for example at over one atmosphere, so that the closed space 2 of the sensor is filled with pressurised Ar gas.

[0032] FIG. 3 is a cross-sectional view of a second embodiment of the acceleration sensor according to the present invention, while FIG. 4 is a plan view of a lower sensor case of the second embodiment of the acceleration sensor according to the present invention. They show an embodiment for detecting the absolute value and the direction of acceleration action (G) acting on the acceleration sensor.

[0033] Referring to FIGS. 3 and 4, an acceleration sensor 11 comprises a lower case 2 formed therein with a cavity 4 and bridges 5 and 15 by, for example, etching in a semiconductor substrate with a fine-processing technique in the semiconductor manufacturing process, and an upper sensor case 3 formed therein with a cavity 7 by etching a semiconductor substrate, a closed space 8 being formed by joining the cases so that the cavities 4 and 7 abut each other.

[0034] Formed on the bridge 5, which extends in the direction in which acceleration (G) is to be measured, are a heater 12 at the center of the bridge 5 in the longitudinal direction, temperature-sensing resistor elements 13, 14 opposite each other at a predetermined distance from the center of the bridge 5 in the longitudinal direction, and a lead pattern formed by using vacuum evaporation and etching of a fine-processing technique.

[0035] Moreover, the bridge 15 is formed coplanar with and perpendicular to the bridge 5, and has a lead pattern for the heater 12 thereon formed by depositing the same metal as for the heater 12 on its surface, and by etching the metal.

[0036] The temperature-sensing resistor elements 13 and 14 are formed in such a manner that a metal pattern is formed by depositing high-melting-point metal such as Pt, Mo, Ni, Au, or Ti, and then etching the metal to form each temperature resistor element with a pattern having a predetermined resistance.

[0037] When thermal stability and durability are required for the temperature-sensing resistor elements 13, 14, the surface of the temperature-sensing resistor elements 13, 14 formed by etching is coated by an oxide coating which is formed by an oxide such as SiN.

[0038] The pair of temperature-sensing resistor elements 13, 14 and the heater 12 are connected through the lead

pattern to respective electrodes 9 provided on the periphery of the lower sensor case 2, electrodes 9 being connected to an external power supply or a detector circuit.

[0039] In the acceleration sensor 11 thus constructed, the heater 12 is heated by supplying external power through the electrode 9 to previously create a thermal equilibrium state with a steep temperature gradient in the closed space 8.

[0040] In the thermal equilibrium state where no acceleration (G) acts, the temperature-sensing resistor elements 13 and 14 are in the same temperature atmosphere so that each of them exhibits the same resistance value if their resistance and characteristics of temperature coefficient are matched (paired).

[0041] When acceleration (G) acts in the equilibrium state in the direction shown in FIG. 4 (indicated by a solid arrow or broken arrow), an air flow is generated in the inert gas, such as nitrogen or argon, enclosed in the closed space 8 to create a thermally unbalanced state in the direction of acceleration action (G) so that the temperature-sensing resistor elements 13 and 14 are subject to different temperatures, respectively.

[0042] Since the temperature-sensing resistor elements 13 and 14 generate opposite changes in resistance in the thermally unbalanced state, the absolute value and the direction of acceleration action (G) are detected by electrically detecting the change in resistance.

[0043] FIG. 5 shows the arrangement of a detection circuit of the acceleration sensor of FIG. 4.

[0044] Referring to FIG. 5, a detector circuit comprises a bridge circuit 16, and reference resistors R1 and R2, and an amplifier 18 which amplifies the differential output of the bridge circuit 16, wherein the bridge circuit 16 constitutes a resistor bridge by connecting the temperature-sensing resistor elements 13 and 14, which is externally provided through the electrodes 9, and reference resistors R1 and R2. A power supply 17 applies power to the bridge circuit 16.

[0045] When no acceleration (G) occurs, the bridge circuit 16 maintains the equilibrium state ( $R_{X1} \cdot R_2 = R_{X2} \cdot R_1$ ) because the temperature-sensing resistor elements 13 and 14 have the same resistance ( $R_{X1}$ ,  $R_{X2}$ ,  $R_{X1} = R_{X2}$ ), and the bridge circuit 16 sets the reference resistors to the same resistance. Then, the bridge output (voltage) becomes zero so that the output  $V_a$  of the amplifier 18 also becomes zero.

[0046] When acceleration (G) occurs, the temperature-sensing resistor elements 13 and 14 exhibit different resistance values ( $R_{X1} > R_{X2}$  or  $R_{X1} < R_{X2}$ ), and the bridge circuit 16 supplies to the amplifier 18 a bridge output (voltage) with negative (-) or positive (+) polarity, depending on the absolute value and the direction of acceleration action (G), and detects the output  $V_a$  corresponding to the bridge output from the amplifier 18.

[0047] Because the temperature-sensing elements 13 and 14 are formed by a fine-processing technique of the semiconductor manufacturing process, it is possible to accurately provide resistance ( $R_{X1}$ ,  $R_{X2}$ ) in a paired state so that the offset of the bridge output (voltage) can be set to a value as close to zero as possible.

[0048] The acceleration sensor 11 employs nitrogen gas with a heat transfer coefficient of about 0.024 (kcal/m·h·°C) as the gas enclosed in the closed space 8. When it is assumed that the heater 12 generates heat of about 0.01 (kcal/h) per square millimeter, the temperature gradient (= heat generation/heat transfer coefficient) for the heater 12 can be set to 400 (°C/mm) to make the temperature distribution in the closed space 8 steep so that acceleration in a very small space on a millimeter order can be detected with high sensitivity.

[0049] It is possible to further improve the sensitivity of acceleration detection by pressurizing the gas to be enclosed in the closed space 8 to a pressure of more than one atmosphere.

[0050] As described, the acceleration sensor 11 can detect acceleration (G) acting on the acceleration sensor with high sensitivity because the closed space 8, the heater 12, and the temperature-sensing resistor elements 13 and 14 can be constructed by using a fine-processing technique of the semiconductor manufacturing process, and their positions can be precisely determined so that a very small acceleration sensor on a millimeter order can be easily obtained.

[0051] In addition, the acceleration sensor 11 separately provides the heater 12 and the temperature-sensing resistor elements 13 and 14, which are positioned opposite to the direction to which acceleration (G) occurs, so that the absolute value and the direction of acceleration (G) acting on the acceleration sensor can be detected with high accuracy.

[0052] If the acceleration sensor is constructed without using the fine-processing technique of the semiconductor manufacturing process as in the conventional sensor, the ability to reduce its size is limited, and the positioning accuracy of the heater and the temperature-sensing resistor elements in the closed space and the pairing of temperature-sensing resistor elements cannot be fully satisfied, with the result that the sensitivity and accuracy in the detection of acceleration (G) are deteriorated.

[0053] FIG. 6 shows a plan view of a lower sensor case of a third embodiment of the acceleration sensor according to the present invention.

[0054] Referring to FIG. 6, an acceleration sensor 21 differs from the acceleration sensor 11 of FIG. 4 in that, in place of the temperature-sensing resistor elements 13 and 14, heat-type temperature-sensing resistor elements 19 and 20 are positioned opposite to each other to eliminate the heater 12 and the bridge 15.

[0055] Because the heat-type temperature-sensing resistor elements 19 and 20 themselves serve as both heaters and temperature-sensing resistor elements, it is possible to create a thermal equilibrium state in temperature distribution with two heaters, and to detect an unbalanced state in the temperature distribution caused by the action of acceleration (G) with two temperature-sensing resistor elements.

[0056] FIGS. 7 and 8 are the arrangement of a fourth embodiment of the acceleration sensor according to the present invention.

[0057] Referring to FIGS. 7 and 8, an acceleration sensor 31 comprises an upper sensor case 3 formed therein with a cavity, a lower sensor case 2 having a cavity 4, a heater 32, and a temperature-sensing resistor element 33, the latter two components being provided at bridges of the cavity 4. A gas 34 is enclosed in a closed space formed by the upper and lower cavities.

[0058] The heater 32 and the temperature-sensing resistor element 33 are resistors which are formed by depositing and etching platinum or tungsten on a bridge (not shown). The gas 34 is a pressurized gas with a low heat transfer coefficient such as nitrogen gas or argon. The lower sensor case 2 and the upper sensor case 3 are closely attached and joined.

[0059] The heater 32 is driven by an external power supply through lead wires 32a and 32b, and generates temperature sufficiently higher than the ambient temperature.

[0060] In addition, the temperature-sensing resistor 33 is previously adjusted to have a predetermined resistance value by supplying a small current from the external power supply through lead wires 33a and 33b.

[0061] The heat generated from the heater 32 is transferred through the gas 34 to create a temperature distribution corresponding to the distance from the heater 32.

[0062] Moreover, use of a pressurized gas with a low heat transfer coefficient such as nitrogen gas or argon creates temperature distribution with a steep temperature gradient corresponding to the distance from the heater 32.

[0063] When acceleration (G) acts in the direction indicated by an arrow shown in FIG. 8 (to the left) under a stable temperature distribution in the closed space, the heated gas 34 moves in the direction of P (to the right) to raise the temperature of the temperature-sensing resistor element 33.

[0064] As the temperature of the temperature-sensing resistor element 33 is raised, the resistance also rises, if the temperature coefficient is positive, to increase the value of the voltage to be detected on the lead wires 33a and 33b.

[0065] On the contrary, if acceleration (G) acts in the opposite direction (to the right), the heated gas 34 moves to the left to reduce the temperature of the temperature-sensing resistor element 33 and also to lower the resistance value of the temperature-sensing resistor element 33 so that the value of the voltage to be detected on the lead wires 33a and 33b is reduced.

[0066] The heater 32 and the temperature-sensing resistor element 33 are positioned on a bridge (not shown) at a predetermined distance D.

[0067] As described, since the acceleration sensor 31 is constructed by positioning the heater 32 and the temperature-sensing resistor element 33, enclosing the pressurized gas with a low heat transfer coefficient such as nitrogen gas or argon in the closed space to increase the temperature gradient and to detect the temperature with a steep temperature gradient from the heater 32, it can detect the temperature change from the change of acceleration (G) with high accuracy.

[0068] FIG. 9 shows a functional block diagram for the detection of acceleration by using the acceleration sensor of FIGS. 7 and 8.

[0069] Referring to FIG. 9, the heater 32 is driven by a constant current source ( $I_H$ ) 35, and generates heat at a high temperature corresponding to the power ( $R_H \cdot I_H^2$ ) based on the resistance  $R_H$  and the current  $I_H$ .

[0070] In addition, the temperature-sensing resistor element 33 is driven by a constant current source ( $I_C$ ) 36, set to a resistance value  $R_C$  which is the sum of a resistance value at the ordinary temperature and a resistance value corresponding to the temperature transferred from the heater 32, and outputs the voltage at a value  $V_C$  ( $R_C \cdot I_C$ ).

[0071] The voltage  $V_G$  is an output of the acceleration sensor 31 corresponding to the resistance  $R_C$  when no acceleration (G) acts, and input to one terminal (for example, the positive input terminal) of a comparator 37 which is constituted by, for example, an operational amplifier.

[0072] The other terminal (for example, a negative input terminal) of the comparator 37 is input with a voltage  $V_S$  from a reference resistor  $R_S$ . The voltage  $V_G$  is set to be equal to the voltage  $V_S$  ( $V_G = V_S$ ), for example, when no acceleration (G) occurs.

[0073] The comparator 37 calculates and outputs the difference  $\Delta V$  between the voltage  $V_G$  and the voltage  $V_S$  ( $= V_G - V_S$ ). Therefore, the difference  $\Delta V$  is zero when no acceleration (G) occurs.

[0074] When the acceleration (G) occurs in the direction shown in the figure, heat transfer is generated from the heater 32 to the temperature-sensing resistor element 33 so that the resistance  $R_C$  of the temperature-sensing resistor element 33 increases, and the difference  $\Delta V$  exceeds zero ( $\Delta V > 0$ ) to provide a positive voltage.

[0075] On the contrary, when the acceleration (G) occurs in the direction opposite to that shown in the figure, the resistance  $R_C$  of the temperature-sensing resistor element 33 decreases, and the difference  $\Delta V$  becomes less than zero ( $\Delta V < 0$ ) to provide a negative voltage.

[0076] An acceleration conversion means 38 has a memory such as a ROM which stores, beforehand, a value of the acceleration  $G_0$  corresponding to the difference  $\Delta V$ , and is arranged to output an acceleration signal  $G_0$  in response to the input of the difference  $\Delta V$ .

[0077] As described above, the acceleration sensor 31 according to the present invention comprises the heater which heats the gas to create a temperature distribution in the space, and the temperature-sensing resistor element which, when acceleration acts on the sensor case, detects a temperature change from the movement of the gas with the temperature distribution so that it can detect the absolute value and the direction of acceleration action. In addition, because the temperature-sensing resistor element is positioned at a predetermined distance from the heater to detect a temperature lower than that of the heater, the acceleration sensor can maintain stable sensitivity while preventing the deterioration or aging which may be caused by high temperature.

[0078] Furthermore, the acceleration sensor 31 according to the present invention employs a pressurized gas with a low heat transfer coefficient as the gas to be enclosed, and can heighten the sensitivity to the temperature detected with the steep temperature gradient so that the acceleration corresponding to the detected temperature can be detected with high accuracy.

[0079] FIGS. 10 and 11 are the arrangement of a fifth embodiment of the acceleration sensor according to the present invention.

[0080] Referring to FIGS. 10 and 11, an acceleration sensor 41 differs from the acceleration sensor 31 shown in FIGS. 7 and 8 in that a temperature-sensing resistor element for temperature compensation 42 is disposed in a cavity 44 formed in a lower sensor case 2 or outside the lower sensor case 2.

[0081] The cavity 44 is formed separately from a cavity 43 to avoid the influence of the heat from the heater 32. Air is enclosed in the closed space so that the temperature-sensing resistor element for temperature compensation 42 detects the ambient temperature.

[0082] When the temperature-sensing resistor element for temperature compensation 42 is arranged on a bridge in the cavity 44, it is formed on the same semiconductor substrate as for the heater 32 and the temperature-sensing resistor element 33 by using a fine-processing technique of the semiconductor manufacturing process.

[0083] As the temperature-sensing resistor element for temperature compensation 42 and the temperature-sensing resistor element 33 are formed on the same semiconductor substrate with the same semiconductor manufacturing process, the temperature-sensing resistor elements with the same characteristics can be formed so that variations in the characteristics and aging between both temperature-sensing resistor elements can be compensated for.

[0084] When the temperature-sensing resistor element for temperature compensation 42 is disposed outside the lower sensor case 2 (the upper sensor case 3 being included), it is attained by attaching, for example, by bonding, to the case the temperature-sensing resistor element for temperature compensation 42 with temperature characteristics matching those of the temperature-sensing resistor element 33.

[0085] When left for a sufficient period of time in a predetermined ambient temperature without supplying current to the heater 32, the heater 32, the temperature-sensing resistor element 33, and the temperature-sensing resistor element for temperature compensation 42 are at ambient temperature.

[0086] In such state, when current is supplied to the heater 32, the heater 32 generates heat corresponding to the power consumption determined by the supplied current and resistance, and thus is heated. It has a temperature equal to the sum of the temperature from the consumed power and the ambient temperature.

[0087] The heat generated from the heater 32 is transferred to the gas 34 such as nitrogen gas or argon to create a temperature distribution with a steep temperature gradient, which is detected by the temperature-sensing resistor element 33. Since the gas 34 and the temperature-sensing resistor element 33 were previously at ambient temperature, the temperature detected by the temperature-sensing resistor 33 is also the sum of the temperature transferred from the heater 32 and the ambient temperature.

[0088] For example, if the reference ambient temperature is 20°C, and the ambient temperature is higher than 20°C by a predetermined temperature  $\Delta T$ , the temperature of the heater 32 is the temperature from the consumed power added to the predetermined temperature  $\Delta T$ , and the temperature detected by the temperature-sensing resistor element 33 is also the temperature of temperature distribution at the location where the temperature-sensing resistor element 33 is positioned added to the predetermined temperature  $\Delta T$ .

[0089] In addition, because the temperature-sensing resistor element for temperature compensation 42 is also set to the ambient temperature (the reference temperature 20°C plus the predetermined temperature  $\Delta T$ ), it is possible to compensate for the temperature detected by the temperature-sensing resistor element 33 based on the temperature detected by the temperature-sensing resistor element for temperature compensation 42.

[0090] Likewise, also, when heat movement is generated by the movement of the gas 34 in the closed space formed by the cavity 43 under the action of acceleration (G), temperature compensation can be attained based on the temperature detected by the temperature-sensing resistor element for temperature compensation 42.

[0091] FIG. 12 shows a functional block diagram for the detection of acceleration by using the acceleration sensor of FIGS. 10 and 11.

[0092] Referring to FIG. 12, the heater 32 and the temperature-sensing resistor element 33 are driven by a constant-current source ( $I_H$ ) 35 and a constant-current source ( $I_L$ ) 36, respectively, and the temperature-sensing resistor element for temperature compensation 42 is driven by a constant-current source ( $I_L$ ) 45 with the same current as that for the

temperature-sensing resistor element 33.

[0093] When the heater 32 is not driven ( $I_H = 0$ ), the temperature-sensing resistor element 33 and the temperature-sensing resistor element for temperature compensation 42 detect the ambient temperature. Because the same temperature characteristics are arranged to be provided for both temperature-sensing resistor elements, the resistance  $R_C$  is equal to the resistance  $R_F$ , and the detection outputs (voltage)  $V_G$  and  $V_R$  from the temperature-sensing resistor element 33 and the temperature-sensing resistor element for temperature compensation 42 become equal ( $V_G = V_R$ ).

[0094] On the contrary, when the heater 32 is driven by the current source ( $I_H$ ), the rise in temperature from the heater 32 is detected, and the resistance  $R_C$  of the temperature-sensing resistor element 33 is increased ( $R_C > R_F$ ) so that the detection output (voltage)  $V_G$  is also increased ( $V_G > V_R$ ).

[0095] An acceleration correction means 46, comprising a temperature comparator 47, a correction value output means 48, and a correction value memory 49, corrects the detection output  $V_G$  from the temperature-sensing resistor element 33 based on the detection output  $V_R$  from the temperature-sensing resistor element for temperature compensation 42 to compensate for the variation in the acceleration (G) due to the ambient temperature to allow the actual acceleration  $G_O$  acting on the acceleration sensor to be determined.

[0096] The temperature comparator 47 consists of a comparator circuit such as a comparator, and stores, beforehand, the detection output  $V_R$  provided by the temperature-sensing resistor element for temperature compensation 42. It compares the detection output  $V_R$  with a reference voltage  $V_i$  corresponding to 20°C, and outputs the difference  $\Delta V_R$  between the detection output  $V_R$  and the reference voltage  $V_i$  to the correction value output means 48.

[0097] The correction value output means 48 receives the detection output  $V_G$  from the temperature-sensing resistor element 33 and the difference  $\Delta V_R$ , reads an acceleration correction value  $\Delta G$  corresponding to the detection output  $V_G$  and the difference  $\Delta V_R$  from the correction value memory 49, and provides it to the acceleration conversion means 38.

[0098] The correction value output means 48 is set to make the acceleration correction value  $\Delta G$  to be output as zero when no acceleration (G) acts at an ambient temperature of, for example, 20°C.

[0099] The correction value memory 49 consists of a memory such as a ROM and sets, in a table, a correction value  $\Delta G$  when the difference  $\Delta V_R$  changes, which correction value is previously determined through experiments for a reference of a difference ( $V_G - \Delta V_R$ ) between the detection output  $V_R$  and the difference  $\Delta V_R$  based on the detection output  $V_R$  and the difference  $\Delta V_R$ .

[0100] The acceleration conversion means 38 comprises a memory such as a ROM for converting the detection output  $V_G$  to a corresponding acceleration  $G_O$ , and a subtractor. The conversion means (38) converts the detection output  $V_G$  to acceleration  $G_O$ , then calculates the difference ( $G_O - \Delta G$ ) of the correction value  $\Delta G$  from the acceleration  $G_O$ , and outputs the difference as the acceleration  $G_O$ .

[0101] The acceleration conversion means 38 is set to make the acceleration  $G_O$  to be output to zero when no acceleration (G) acts at an ambient temperature of, for example, 20°C.

[0102] Thus, as the acceleration  $G_O$  to be output is set to zero when no acceleration (G) acts at an ambient temperature of 20°C, and the acceleration correction means 46 compensates for the temperature according to the change in the ambient temperature, it is possible to set the acceleration  $G_O$  output from the acceleration conversion means 38 always to zero.

[0103] When acceleration (G) acts, as the detection voltage  $V_G$  of the temperature-sensing resistor element 33 increases or decreases, the acceleration  $G_O$  corresponding to the detection output  $V_G$  and corrected for the acceleration with respect to the ambient temperature (correction value  $\Delta G$ ) can be obtained from the acceleration conversion means 38.

[0104] The acceleration correction means 46 is an embodiment of an arrangement assuming a case where the ambient temperature changes from the temperature detected at a state where the temperature-sensing resistor element 33 is at the ambient temperature of 20°C and no acceleration (G) occurs, and where the output  $G_O$  from the acceleration conversion means 38 corresponding to the detection output  $V_G$  is nonlinear.

[0105] FIG. 13 shows another embodiment of the acceleration correction means in FIG. 12.

[0106] This embodiment represents a case in which the output  $G_O$  from an acceleration conversion means 50 and the detection output  $V_{GO}$  from an acceleration correction means 46' are linear.

[0107] The acceleration correction means 46' comprises a comparator circuit such as a comparator and an arithmetic circuit such as a subtractor, and calculates and outputs a difference  $V_{GO}$  ( $V_G - V_R$ ) between the detection output  $V_G$  from the temperature-sensing resistor element 33 and the detection output  $V_R$  from the temperature-sensing resistor element for temperature compensation 42.

[0108] The acceleration conversion means 50 has a memory such as a ROM for converting the difference output  $V_{GO}$  from the acceleration correction means 49 into a corresponding acceleration  $G_O$ , converts the difference output  $V_{GO}$  into acceleration  $G_O$ , and outputs it.

[0109] As described above, since the acceleration sensor 41 according to the present invention comprises the temperature-sensing resistor element for temperature compensation for detecting the ambient temperature, and the ac-



celeration correction means for correcting the output signal output from the temperature-sensing resistor element based on the output signal from the temperature-sensing resistor element for temperature compensation, it can detect accurately the acting acceleration by compensating for the influence from the ambient temperature.

[0110] FIGS. 14 and 15 are the arrangement of a sixth embodiment of the acceleration sensor according to the present invention.

[0111] Referring to FIGS. 14 and 15, an acceleration sensor 51 comprises an upper sensor case 3 formed therein with a cavity, a lower sensor case 2 having a cavity 4, temperature-sensing resistor elements 52 and 53 provided on bridges in the cavity 4, and a pair of reference resistors 54 and 55 externally connected to the temperature-sensing resistor elements 52 and 53 to form a bridge circuit 56, a gas 34 being enclosed in a closed space formed by the upper and lower sensor cases.

[0112] The heat-type temperature-sensing resistor elements 52 and 53 comprise resistors, each of which is formed by depositing and etching platinum or tungsten on a bridge (not shown). The gas 34 employed is a pressurized gas with a low heat transfer coefficient such as nitrogen gas or argon. The lower sensor case 2 and the upper sensor case 3 are closely attached and joined.

[0113] In addition, the heat-type temperature-sensing resistor elements 52 (resistor R1) and 53 (resistor R2) are connected by lead wires which are led outside of the sensor case for connecting with the reference resistors 54 (resistor r1) and 55 (resistor r2), which are disposed outside the sensor case, to form a bridge circuit 56. The bridge circuit 56 has terminals (56a - 56d), as shown in FIG. 15, and consists of four resistors.

[0114] When power (for example, from a power supply  $V_1$ ) is applied across the terminals (56a - 56b), the heat-type temperature-sensing resistor elements 52 and 53 generate heat corresponding to the power consumed, and generate, as a heat source with a temperature sufficiently higher than the ambient temperature, a temperature distribution corresponding to the distance from the heat-type temperature-sensing resistor elements 52 and 53 in the closed space.

[0115] In this state, the heat-type temperature-sensing resistor elements 52 and 53 have resistances R1 and R2, respectively, so that voltage  $V_X$  divided by the resistor R1 and R2 is generated at the terminal (56c).

[0116] In contrast, voltage  $V_Y$  divided by resistances r1 and r2 of the reference resistors 54 and 55 is generated at the terminal (56d). Thus, resistances R1, R2, r1 and r2 are set in such a manner that the output of the bridge circuit 56 (potential difference  $V_X - V_Y$ ) is in the equilibrium state (output voltage = 0 V) when no acceleration (G) occurs ( $R1 = R2, r1 = r2$ ).

[0117] In this state, the temperature distribution in the closed space caused by heat generated from the heat-type temperature-sensing resistor elements 52 and 53 is also in the equilibrium state.

[0118] In addition, the employment of the pressurized gas with a low heat transfer coefficient, such as nitrogen gas or argon, as the gas 34 results in a temperature distribution corresponding to the distance from the heat-type temperature-sensing resistor elements 52 and 53 in the closed space with a steep temperature gradient.

[0119] When acceleration (G) acts in the direction indicated by the arrow shown in FIG. 15 in the equilibrium state, the gas 34 moves in the direction of P to cause heat movement from the heat-type temperature-sensing resistor element 52 to the heat-type temperature-sensing resistor element 53.

[0120] When the heat movement (direction of P) occurs, the thermal equilibrium in the closed space is destroyed, the temperature of the heat-type temperature-sensing resistor element 52 decreases, and the temperature of the heat-type temperature-sensing resistor element 53 increases so that the resistance R1 of the heat-type temperature-sensing resistor element 52 decreases and the resistance R2 of the heat-type temperature-sensing resistor element 53 increases.

[0121] When, with the occurrence of acceleration (G), the resistance R2 increases and the resistance R1 decreases, the output of the bridge circuit 56 also becomes unbalanced so that the potential difference  $V_X - V_Y$  detects a positive value ( $V_X - V_Y > 0$ ) corresponding to the acceleration (G).

[0122] In contrast, when acceleration (G) acts in the direction opposite to the arrow shown in FIG. 15, a reverse phenomenon occurs, that is, the resistance R1 increases and the resistance R2 decreases so that the output of the bridge circuit 56 detects a negative potential value ( $V_X - V_Y < 0$ ) corresponding to the acceleration (G).

[0123] Thus, the acceleration sensor 51 detects the magnitude of the acting acceleration (G) with the absolute value of the output of the bridge circuit 56 (potential difference  $V_X - V_Y$ ), and the acting direction of acceleration (G) with the sign of the output (positive or negative of potential difference  $V_X - V_Y$ ).

[0124] The output of the bridge circuit 56 (potential difference  $V_X - V_Y$ ) will be explained in the following:

[0125] FIG. 16 shows a bridge circuit diagram in the acceleration sensor of FIGS. 14 and 15.

[0126] Referring to FIG. 16, the bridge circuit 56 consists of the resistances R1 and R2 of the heat-type temperature-sensing resistor elements 52 and 53, and the resistances r1 and r2 of the reference resistors 54 and 55, a power supply (for example, the voltage source  $V_1$ ) being connected between the terminals (56a - 56b), the output occurring across the terminals (56c - 56d).

[0127] The voltage  $V_X$  at the terminal (56c) and the voltage  $V_Y$  at the terminal (56d) with respect to ground (GND) is calculated by using equation 1, as follows:

$$V_X = R_2 \cdot V_I / (R_1 + R_2),$$

and

$$V_Y = r_2 \cdot V_I / (r_1 + r_2) \quad (1)$$

[0128] Based on equation 1, the output potential difference of the bridge circuit 56  $V_O (= V_X - V_Y)$  can be represented by the following, equation 2:

$$\begin{aligned} V_O &= V_X - V_Y \\ &= (R_2 \cdot r_1 - R_1 \cdot r_2) V_I / \{(R_1 + R_2) \cdot (r_1 + r_2)\} \end{aligned} \quad (2)$$

[0129] In equation 2, by setting  $R_1 = R_2$  and  $r_1 = r_2$ , the output potential difference  $V_O = 0$  can be obtained in the equilibrium state where no acceleration (G) occurs.

[0130] When, in the equilibrium state, the acceleration (G) shown in FIG. 15 occurs, and the heat movement (direction of P) causes a decrease in the resistance  $R_1$  by  $\Delta R$  and an increase in the resistance  $R_2$  by  $\Delta R$ , the output potential difference  $V_O (= V_X - V_Y)$  becomes the value represented by equation 3:

$$\begin{aligned} V_O &= V_X - V_Y \\ &= \Delta R \cdot (r_1 + r_2) V_I / \{(R_1 + R_2) \cdot (r_1 + r_2)\} \\ &= \Delta R \cdot V_I / 2R \end{aligned} \quad (3)$$

where,  $R_1 = R_2 = R$ ,  $r_1 = r_2 = r$ .

[0131] Thus, the output potential difference  $V_O$  can provide a value proportional to the variation  $\Delta R$  of resistance corresponding to acceleration (G).

[0132] However, when acceleration (G) acts in a direction opposite to that shown in FIG. 15, the output potential difference  $V_O$  provides a value with the opposite-sign to equation 3 ( $-\Delta R \cdot V_I / 2R$ ).

[0133] As described above, because, in the acceleration sensor 51 according to the present invention, a pair of heat-type temperature-sensing resistor elements is disposed with a predetermined distance in a closed space containing a pressurized gas with a low heat transfer coefficient, and a bridge circuit is constituted by a pair of heat-type temperature-sensing resistor elements and a pair of external reference resistors, it is possible to detect heat movement in the case, which is caused by the action of acceleration, with the change in resistance of the pair of heat-type temperature-sensing resistor elements, to detect the absolute value of acceleration at a high accuracy with the output voltage of the bridge circuit and its sign, and to detect the direction in which acceleration is acting.

[0134] FIGS. 17 and 18 are the arrangement of a seventh embodiment of the acceleration sensor according to the present invention.

[0135] Referring to FIGS. 17 and 18, the acceleration sensor 61 differs from the acceleration sensor 51 shown in FIG. 14 in that heat-type temperature-sensing resistor elements 62 and 63 are disposed at a predetermined distance D in a closed space in a lower sensor case 2, and a plurality of heaters 64 ( $R_{11} - R_{1n}$ ,  $R_{21} - R_{2n}$ ,  $R_{31} - R_{3n}$ ) are positioned on both sides of the heat-type temperature-sensing resistor elements 62 and 63.

[0136] Furthermore, similar to FIG. 15, the heat-type temperature-sensing resistor elements 62 and 63, and the reference resistors 54 and 55 constitute the bridge circuit 56 shown in FIG. 15.

[0137] The heaters 64 ( $R_{11} - R_{1n}$ ,  $R_{21} - R_{2n}$ ,  $R_{31} - R_{3n}$ ) are heated by, for example, connecting the elements in series and connecting a power supply across the terminals (56e - 56f).

[0138] In addition, a voltage source  $V_I$  is connected across the terminals (56a - 56b) of the bridge circuit 56 to heat the heat-type temperature-sensing resistor elements 62 and 63.

[0139] It is assumed that the heat-type temperature-sensing resistor elements 62 and 63 have resistances  $R_1$  and  $R_2$  when the temperature distribution in the closed space caused by the heat generation of the heat-type temperature-sensing resistor elements 62 and 63, and the heaters 64 ( $R_{11} - R_{1n}$ ,  $R_{21} - R_{2n}$ ,  $R_{31} - R_{3n}$ ) reaches equilibrium. Then, the bridge circuit 56, constituted by resistances  $r_1$  and  $r_2$  of the standard resistors 54 and 55 and resistances  $R_1$  and

R2, is set in that state in which its output (output potential difference  $V_O$ ) is in an equilibrium state ( $V_X - V_Y = 0$ ).

[0140] When heat movement is generated in the closed space in the direction of the arrow (direction of P) by the action of acceleration (G) in the direction shown in FIG. 18, heat moves from the heat-type temperature-sensing resistor element 62 to the heat-type temperature-sensing resistor element 63 as described for FIG. 15 to decrease the resistance R1 and to increase the resistance R2.

[0141] Since the decrease in the resistance R1 and the increase in the resistance R2 provide a value larger than the variation in FIG. 15 (for example,  $k \cdot \Delta R$ ) because of the heat movement in the heaters 64 ( $R_{11} - R_{1n}, R_{21} - R_{2n}, R_{31} - R_{3n}$ ), the bridge output  $V_O$  ( $V_X - V_Y$ ) becomes  $k \cdot \Delta R \cdot V_i / 2R$  times the relationships of equations 1 - 3.

[0142] Thus, because the acceleration sensor 61 is provided with a plurality of heaters 64, the movement of heat (temperature change) can be set at a linear value, and provide larger bridge output than that of the arrangement of FIG. 14 can be obtained for the same acceleration (G) so that the detection accuracy can be improved.

[0143] In contrast, when the direction of acceleration (G) is reversed, the bridge output  $V_O$  of  $-k \cdot \Delta R \cdot V_i / 2R$  is obtained.

[0144] It is the same as in the arrangement of FIG. 14 to employ a pressurized gas with a low heat transfer coefficient such as nitrogen gas or argon as the gas 34 used.

[0145] As described, since the acceleration sensor 61 according to the present invention provides a plurality of heaters together with a pair of heat-type temperature-sensing resistor elements in the closed space, the heat movement (temperature change) in the closed space can be increased so that the absolute value of acceleration can be detected with a high accuracy.

[0146] FIGS. 19 and 20 are the arrangement of a eighth embodiment of acceleration sensor according to the present invention.

[0147] Referring to FIGS. 19 and 20, an acceleration sensor 71 differs from the arrangements shown in FIGS. 14 and 15 in that heat-type temperature-sensing resistor elements 74 and 75 corresponding to the standard resistor (r1) 54 and the standard resistor (r2) 55 shown in FIG. 15 are provided in the closed space in the lower sensor case 2 together with the heat-type temperature-sensing resistor elements 72 and 73, and in that a bridge circuit 56 is constituted by the heat-type temperature-sensing resistor elements 72, 73, 74 and 75.

[0148] A power supply  $V_i$  is connected across the terminals (56a - 56b) to heat the heat-type temperature-sensing resistor elements 72, 73, 74, and 75. The resistance R1, R2, r2, and r1 are set to values to make equilibrium ( $V_X - V_Y = 0$ ) the output  $V_O$  (across the terminals 56c - 56b) of the thermally balanced bridge circuit 56 in the closed space.

[0149] When the movement of heat in the direction of P is generated in the closed space as acceleration (G) acts in the direction of the arrow, heat moves from the heat-type temperature-sensing resistor elements 72 and 74 to the heat-type temperature-sensing resistor elements 73 and 75 to decrease the resistances R1 and r2 and to increase the resistances R2 and r1.

[0150] When it is assumed that the decrease in the resistances R1 and r2 is  $-\Delta R$  and  $-\Delta r$ , and the increase in the resistances R2 and r1 is  $\Delta R$  and  $\Delta r$ , the bridge output  $V_O$  ( $V_X - V_Y$ ) is represented by equation 4:

$$\begin{aligned} V_O &= V_X - V_Y \\ &= (R \cdot \Delta r + r \cdot \Delta R) V_i / (2R \cdot r) \end{aligned} \quad (4)$$

where  $R1 = R2 = R$ , and  $r1 = r2 = r$

[0151] Thus, the acceleration sensor 71 provided with the heat-type temperature-sensing resistor elements 74 and 75 can set the movement of heat (temperature change) to a large value, and a larger bridge output can be obtained for the same acceleration (G) than for the arrangements of FIGS. 14 and 15 so that the detection accuracy of the sensor can be made higher.

[0152] It is the same as in the arrangement of FIG. 14 to employ a pressurized gas with a low heat transfer coefficient such as nitrogen gas or argon as the gas 34 used, and to position the heat-type temperature-sensing resistor elements 72 and 73 at a relative distance D.

[0153] As described above, since, in the acceleration sensor 71 according to the present invention, two pairs of heat-type temperature-sensing resistor elements are provided in the closed space, and the bridge circuit is constituted by four heat-type temperature-sensing resistor elements, the absolute value of acceleration can be detected at a higher accuracy.

[0154] FIG. 21 is the arrangement of essential components of a ninth embodiment of an acceleration sensor according to the present invention.

[0155] Referring to FIG. 21, an acceleration sensor 81 is an embodiment of a three-axis acceleration sensor, and constituted by four types of semiconductor substrates 82 - 85.

[0156] The semiconductor substrates 82 - 85 are formed therein with a cavity, a space, heaters, and temperature-

sensing resistor elements by a fine-processing technique in the semiconductor manufacturing process such as etching or depositing.

[0157] Dimensions and placement of the space, the heaters, the temperature-sensing elements, and external connection pads can be very finely determined by a mask so that they can be attained with a high accuracy.

[0158] The semiconductor substrate 82 constitutes the cover for a sensor case for the acceleration sensor 81 in which a cavity 86 is very finely processed and formed by etching.

[0159] The semiconductor substrate 83 is formed with a temperature-sensing resistor element Z1 upward in the direction of the Z axis, external connection pads (91a) and (92b) for connecting the temperature-sensing resistor element Z1 to the outside, and a space 87 extending through the Z axis.

[0160] The temperature-sensing resistor element Z1 is formed by etching based on a fine pattern diagram which represents a mask for manufacturing conductors to be formed on a bridge (not shown), which is formed on the top of the semiconductor substrate by, for example, etching, by depositing or crystal growing metal such as platinum or tungsten.

[0161] The temperature-sensing resistor element Z1 is formed on the diagonal line, or in the X direction, or in the Y direction, so that it is positioned at the center of the top of the substrate.

[0162] The external connection pads (91a) and (91b), and a lead pattern for electrically connecting the temperature-sensing resistor element Z1 and the external connection pads (91a) and (91b) are also formed by depositing or crystal growing metal such as platinum or tungsten as in the temperature-sensing resistor element Z1.

[0163] The semiconductor substrate 83 is formed of a sufficiently large size so that the external connection pads (91a) and (91b) appear on the surface of the substrate when it is stuck together with the semiconductor substrate 82, and the upper surface of the space 87 aligns the plane of the cavity 86 in the semiconductor substrate 82.

[0164] The semiconductor substrate 84 includes a heater H, pairs of temperature-sensing resistor elements X1 and X2, and Y1 and Y2 facing the heater H and respectively disposed in the directions of the X and Y axes, external connection pads (93a, 93b, 94a, 94b, 95a, 95b, 96a, 96b, 97a, and 97b) for connecting the heater H, and the temperature-sensing resistor elements X1, X2, Y1, and Y2 to the outside, and a space 88 extending through the Z axis.

[0165] The heater H is formed so as to be positioned at the center of the space 88 on the top of the semiconductor substrate 84.

[0166] The heater H, and the pairs of temperature-sensing resistor elements X1 and X2, and Y1 and Y2 are formed by depositing and etching metal such as platinum and tungsten on a bridge (not shown) which is formed by etching as in the temperature-sensing resistor element Z1 on the semiconductor substrate 83.

[0167] The heater H and the temperature-sensing resistor elements X1, X2, Y1, and Y2 differ in that the resistance of the heater H is lower than the temperature-sensing resistor elements X1, X2, Y1, and Y2.

[0168] A lead pattern is also formed by deposition or the like and etching metal such as platinum or tungsten for electrically connecting the heater H and the temperature-sensing resistor elements X1, X2, Y1, and Y2 to the external connection pads (93a, 93b, 94a, 94b, 95a, 95b, 96a, 96b, 97a, and 97b).

[0169] The space 88 is formed in the same size as the space 87 to pass through the Z axis.

[0170] The semiconductor substrate 84 is formed of a sufficiently large size so that the external connection pads (93a, 93b, 94a, 94b, 95a, 95b, 96a, 96b, 97a, and 97b) appear on the surface of the substrate when it is stuck together with the semiconductor substrate 83, and the upper surface of the space 88 aligns the plane of the space 87 in the semiconductor substrate 83.

[0171] The semiconductor substrate 85 is formed with a temperature-sensing resistor element Z2 downward in the direction to the Z axis, external connection pads (92a) and (92b) for connecting the temperature-sensing element Z2 to the outside, and a space 89 which forms the bottom of the sensor 81 case downward in the direction of the Z axis.

[0172] The temperature-sensing resistor element Z2 is arranged to be paired with the temperature-sensing resistor element Z1 on the semiconductor substrate 83 with respect to the heater H on the semiconductor substrate 84.

[0173] The temperature-sensing resistor element Z2 is formed in a manner similar to that for the temperature-sensing resistor element Z1 on the semiconductor substrate 83. The semiconductor substrate 85 is formed of a sufficiently large size so that the external connection pads (92a) and (92b) appear on the surface of the substrate when it is stuck together with the semiconductor substrate 84, and the upper surface of the space 89 aligns the plane of the space 88 in the semiconductor substrate 84.

[0174] After the semiconductor substrates 82 - 85 are completely arranged, the semiconductor substrates 83, 84 and 85 are stacked and joined in the direction of the Z axis direction so as to align the spaces 87 - 89, and a pressurized gas with a low heat transfer coefficient such as nitrogen or argon is introduced into the space while joining the semiconductor substrate 82 to form a pyramid acceleration sensor 81.

[0175] Positioning recesses may be provided in the upper surfaces of the semiconductor substrates 83 - 85 in joining the semiconductor substrates 82 - 85.

[0176] Although the embodiment is described for a three-axis (X, Y, and Z axes) acceleration sensor, a two-axis (X and Y axes) acceleration sensor can be constituted by eliminating the semiconductor substrates 83 and 85, and pro-

viding a bottom on the space 88 in the semiconductor substrate 84 similar to the space 89 in the semiconductor substrate 85.

[0177] The thus-constituted acceleration sensor 81 can attain accurate positioning of the heater H and the temperature-sensing resistor elements X1, X2, Y1, Y2, Z1, and Z2 by using a fine-processing technique in the semiconductor manufacturing process so that alignment can be accurately achieved,

[0178] Also, since the temperature-sensing resistor elements X1, X2, Y1, Y2, Z1, and Z2 are formed on the same semiconductor substrate or the semiconductor substrates of the same production lot, the acceleration sensor 81 can be obtained with good pairing (resistivity and temperature coefficient) of X1 and X2, Y1 and Y2, and Z1 and Z2.

[0179] Furthermore, because the acceleration sensor 81 is formed by the fine-processing technique in the semiconductor manufacturing process, it can be produced in the minimum size necessary for a sensor so that miniaturization can be attained.

[0180] FIGS. 22a and 22b show in perspective and top plan view the appearance of the acceleration sensor shown in FIG. 21.

[0181] Referring to FIGS. 22a and 22b, the acceleration sensor 81 has the semiconductor substrates 82 - 85 described for FIG. 21, and is constituted in a pyramid acceleration sensor by stacking and joining the semiconductor substrates 82 - 85 in the direction of the Z axis.

[0182] Disposed in the closed space 90 are the heater H, and the temperature-sensing resistor elements X1, X2, Y1, Y2, Z1, and Z2 for detecting acceleration in the three axes (X, Y, and Z axes). The pressurized gas 91 with a low heat transfer coefficient such as nitrogen or argon is also enclosed in the space 90.

[0183] In addition, disposed on the surface of the acceleration sensor 81 are the external connection pads of the heater H (bonding pads 91a - 97b) and of the temperature-sensing resistor elements X1, X2, Y1, Y2, Z1, and Z2 for connection with an external acceleration detector circuit (not shown).

[0184] Detection of acceleration by the acceleration sensor 81 according to the present invention will be explained in the following section:

[0185] FIG. 23 is a diagram illustrating the operation of the acceleration sensor shown in FIG. 21.

[0186] Referring to FIG. 23, in the closed space 90 of the acceleration sensor 81 shown in FIGS. 21 and 22, the heater H is disposed at the center of the X-Y plane at the center of the Z axis, and a pair of temperature-sensing resistor elements X1 (resistance R1) and X2 (resistance R2); and a pair of temperature-sensing resistor elements Y1 (resistance R3) and Y2 (resistance R4) are disposed opposite to each other with respect to the X and Y axes, respectively, in symmetry with the heater H (resistance R).

[0187] In addition, a pair of temperature-sensing resistor elements Z1 (resistance R5) and Z2 (resistance R6) is disposed opposite to each other with respect to the Z axis in symmetry with the heater H (resistance R).

[0188] Furthermore, enclosed in the closed space 90 is a pressurized gas 91 with a low heat transfer coefficient such as nitrogen or argon. The heater H generates Joule heating corresponding to the electrical power ( $V_0^2/R$  or  $I_0^2 \cdot R$ ) by driving it with an external power supply (for example, a voltage source  $V_0$  or a current source  $I_0$ ).

[0189] The gas 91 is heated by Joule heating, and a temperature distribution inversely proportional to the distance from the heater H is created in the closed space 90 with a steep temperature gradient.

[0190] Because the temperature-sensing resistor elements X1, X2, Y1, Y2, Z1, and Z2 are positioned at equal distances from the heater H in the X, Y, and Z axes, respectively, when no acceleration (G) acts on the acceleration sensor 81, the temperature-sensing resistor elements are in an equal temperature environment and thermally balanced, and the resistance R1 - R6 are in the relationships of  $R1 = R2$ ,  $R3 = R4$ , and  $R5 = R6$ .

[0191] When acceleration (G) occurs, for example, in the direction of the X (-X) axis as in FIG. 23 in the thermally balanced state, the temperature distribution in the closed space 90 moves in the direction opposite to the direction of acceleration (G), the temperature balance between the temperature-sensing resistor elements X1 and X2 is destroyed to increase the temperature of the temperature-sensing resistor element X1, and to decrease that of the temperature-sensing resistor element X2.

[0192] Because the increase in the temperature of the temperature-sensing resistor element X1 increases the resistance R1, while a decrease in the temperature of the temperature-sensing resistor element X2 decreases the resistance R2, when an arrangement is made to detect acceleration (G) with a value corresponding to the resistance difference ( $R1 - R2$ ) between the resistances R1 and R2, the resistance difference ( $R1 - R2$ ) becomes a positive value ( $R1 - R2 > 0$ ) so that the magnitude of acceleration (G) can be detected from the value corresponding to the resistance difference, and the direction of acceleration (G) can be detected from the sign (+ or -) of the resistance difference.

[0193] In contrast, when acceleration (G) acts in a direction opposite to that in FIG. 23, the resistance difference ( $R1 - R2$ ) takes a negative value ( $R1 - R2 < 0$ ) so that the magnitude and the direction of acceleration (G) can be detected from a value corresponding to the resistance difference and its sign (+ or -), respectively.

[0194] When acceleration (G) acts in the direction of the X axis, the temperature-sensing resistor elements Y1 and Y2, as well as Z1 and Z2 in the directions of the Y and Z axes are thermally balanced, therefore both the resistance difference ( $R3 - R4$ ) and ( $R5 - R6$ ) becomes zero, and the temperature-sensing resistor elements are not affected by

acceleration (G).

[0195] Similarly, when acceleration (G) acts in the direction of the Y or Z axis, the thermal balance is destroyed in the temperature-sensing resistor elements Y1 and Y2 or Z1 and Z2 positioned in the direction of acceleration (G) so that the acceleration (G) can be detected from a value corresponding to the resistance difference (R3 - R4) or (R5 - R6) and their sign (+ or -).

[0196] FIGS. 24 - 27 are diagrams of acceleration detector circuits of the acceleration sensor shown in FIG. 21.

[0197] FIG. 24 shows a diagram of the heater driving circuit, FIG. 25 a diagram of the acceleration detector circuit in the direction of the X axis, FIG. 26 a diagram of the acceleration detector circuit in the direction of the Y axis, and FIG. 27 a diagram of the acceleration detector circuit in the direction of the Z axis.

[0198] Although FIGS. 24-27 show examples in which the driving power supply is constituted by a current source ( $I_O$ ), they may be constituted by a voltage source ( $V_O$ ).

[0199] The heater driving circuit shown in FIG. 24 supplies current to the resistance R of the Heater H from a current source ( $I_O$ ) to generate Joule heating corresponding to the electrical power ( $I_O^2 \cdot R$ ).

[0200] The acceleration detector circuit in the direction of the X axis shown in FIG. 25 constitutes a resistor bridge circuit with the temperature-sensing resistor elements X1 (resistance R1) and X2 (resistance R2), and standard resistors Ro1 and Ro2, and is arranged to output difference  $V_{OX}$  ( $V_{X1} - V_{X2}$ ) based on the bridge output voltage  $V_{X1}$  and  $V_{X2}$  through a differential amplifier  $A_X$ , and to obtain a detection output corresponding to acceleration (G) acting in the direction of the X axis.

[0201] FIGS. 26 and 27 similarly constitute a resistor bridge circuit, and are arranged to output difference  $V_{OY}$  ( $V_{Y1} - V_{Y2}$ ) and  $V_{OZ}$  ( $V_{Z1} - V_{Z2}$ ) based on the bridge output voltage  $V_{Y1}$  and  $V_{Y2}$ , as well as  $V_{Z1}$  and  $V_{Z2}$ , and to obtain a detection output corresponding to acceleration (G) acting in the direction of the Y or Z axis direction.

[0202] As described, because the absolute values and the directions of acceleration (G) acting in the X, Y and Z axis directions can be detected from the difference ( $V_{OX}$ ,  $V_{OY}$  and  $V_{OZ}$ ) and their sign (+ or -), it is possible to detect acceleration (G) acting in any of three dimensional directions by providing a calculation means for calculating the mean square  $\sqrt{(V_{OX}^2 + V_{OY}^2 + V_{OZ}^2)}$  and an orientation determination means for determining the quadrant of a three-dimensional XYZ coordinate system from the sign (+ or -) of each difference.

[0203] As described above, since the acceleration sensor 81 according to the present invention is arranged by forming the sensor case forming the closed space, the heaters, a pair of temperature-sensing resistor elements disposed in each of multiple axis directions on a plurality of separate semiconductor substrates with the semiconductor manufacturing process, and by joining the plurality of semiconductor substrates in one direction, it is possible to easily align the plurality of temperature-sensing resistor elements with the multiple axes which are orthogonal to each other, and to form the temperature-sensing resistor elements with matched characteristics so that a very small acceleration sensor can be attained with less variation and higher accuracy.

[0204] Furthermore, since the acceleration sensor 81 according to the present invention employs pressurized gas with a low heat transfer coefficient as the gas to be enclosed in the closed space, it is possible to create a steep temperature gradient and to attain a sensor with high sensitivity.

[0205] As described above in detail for various embodiments, because the present invention very finely processes the semiconductor substrates and the like with a fine-processing technique in the semiconductor manufacturing process, accurately forms the sensor case, the heater, the temperature-sensing resistor element, the heat-type temperature-sensing resistor element and the like, and accurately determines their relative placement, the present invention can provide a miniaturized and economic acceleration sensor which can detect acceleration acting on the sensor with a high accuracy.

[0206] Furthermore, because the present invention encloses a pressurized inert gas with a low heat transfer coefficient in the closed space formed by the sensor case, the present invention can provide an acceleration sensor which can detect acceleration acting on the sensor with a high sensitivity by increasing the temperature gradient in the closed space.

[0207] Furthermore, because the present invention disposes a pair of temperature-sensing resistor elements with good pairing (resistivity, and temperature coefficient) in the direction of acceleration, it can provide an acceleration sensor which can detect the absolute value and the direction of acceleration more accurately.

[0208] Furthermore, because the present invention disposes a pair of temperature-sensing resistor elements with good pairing (resistivity, and temperature coefficient) in each of the three-dimensional axis directions, it can provide an acceleration sensor which can accurately detect acceleration acting in any of the three-dimensional directions.

[0209] The invention is not limited to the disclosed embodiments, which are given by way of example only, and various modifications can be envisaged, including combinations of the features of the embodiments described.

## Claims

1. An acceleration sensor (1;11;21;31;41;51;61;71;81) including at least one temperature-sensing resistor means (6; 13;19;33;52;62) disposed, in use, within a closed space (8), gas (34) in said closed space (8) being heated, and wherein the resistance of said resistor means changes when an acceleration acts on said sensor due to flow of said gas (34) over said resistor means, characterized in that said sensor comprises a semiconductor or insulating substrate (2) having a cavity (4;43) therein, and a projection (5,15) of the semiconductor or insulating substrate extending in the space at least part way across said cavity (4), and in that said resistor means is integrally formed on said projection means (5).
2. The sensor of claim 1, wherein said resistor means is a heat-type temperature-sensing resistor element (6) which is used to both heat said gas and indicate acceleration by changing resistance.
3. The sensor of claim 1 or 2, wherein said projection means (5) bridges the center of said cavity (4), and said temperature-sensing resistor means (6) is disposed at the center of said space.
4. The sensor of claim 1, further including heater means (12;32) disposed in said space for heating the gas, wherein said temperature-sensing resistor means (13;33) is spaced from said heater means (12;32), and said heater means (12;32) is formed on said projection means (5).
5. The sensor of claim 4, further including a second temperature-sensing resistor means (14) disposed opposite said first resistor means (13), with said heater means (12) disposed centrally between said first and second resistor means (13,14).
6. The sensor of claim 5, further including a detection circuit for detecting the change in resistance of one or both of said first and second resistor means (13,14), said detection circuit comprising a bridge circuit (16) including said first and second resistor means (13,14) and first and second reference resistors (R1,R2) connected respectively therewith to form a resistor bridge, and an amplifier (18) for amplifying the differential output of said bridge circuit (16).
7. The sensor of claim 1, further including a second temperature-sensing resistor means (20) disposed opposite said first resistor means (19), wherein said first and second resistor means (19,20) are both formed of a heat-type temperature-sensing resistor element.
8. The sensor of claim 7, wherein said projection means comprises first and second projections extending into said cavity (4) from opposite directions, and said first and second resistor means (19,20) are formed on said first and second projections respectively.
9. The sensor of claim 4, wherein said heater means (32) and said resistor means (33) are disposed side by side and spaced at a predetermined distance.
10. The sensor of claim 4 or 9, further including a comparator (37) for comparing the output of said resistor means (33) with a reference resistor (Rs) to determine a change in resistance of said resistor means.
11. The sensor of claim 4, 9 or 10, further including a further temperature-sensing resistor means (42) for detecting ambient temperature, and an acceleration correction means (46;46') for correcting the output from said first resistor means (33) based on the ambient temperature detected by said further resistor means (42).
12. The sensor of claim 11, wherein said semiconductor or insulating substrate further includes a second cavity (44) separated from said first-mentioned cavity (43) and filled with ambient air, said further resistor means (42) being disposed in said second cavity (44) and formed on a second projection means of insulating material extending in said second cavity (44).
13. The sensor of claim 11, wherein said further resistor means (42) is disposed outside said semiconductor or insulating substrate (2) and attached to said semiconductor or insulating substrate.
14. The sensor of claim 1, further including a second temperature-sensing resistor means (53;63;73) disposed in said space and separated from said first resistor means (52;62;72) by a predetermined distance, wherein said first and

second resistor means are both formed of a heat-type temperature-sensing resistor element and connected with first and second reference resistors (r1,r2), respectively, to form a bridge circuit (56).

15. The sensor of claim 14, wherein said first and second reference resistors (r1,r2) are disposed outside said semiconductor or insulating substrate.
16. The sensor of claim 14 or 15, further including a plurality of heaters (64) disposed on both sides or each of said first and second temperature-sensing resistor means (62,63).
17. The sensor of claim 14, wherein said first and second reference resistors (r1,r2) are disposed in said space and formed by third and fourth heat-type temperature-sensing resistor means (74,75).
18. The sensor of claim 1, further including a heater (H) disposed in said space for heating the gas therein, wherein said resistor means comprises a pair of first temperature-sensing resistor elements (X1,X2) disposed opposite to each other with respect to a first axis in symmetry with said heater (H) so as to detect acceleration in the direction of said first axis, and a pair of second temperature-sensing resistor elements (Y1,Y2) disposed opposite to each other with respect to a second axis perpendicular to said first axis in symmetry with said heater (H) so as to detect acceleration in the direction of said second axis.
19. The sensor of claim 18, further including second and third semiconductors or insulating substrates (83,85) mounted on opposite surfaces of said first-mentioned substrate (84) and each having a cavity (86,89) therein communicating with the cavity (88) in said first-mentioned substrate (84), wherein said resistor means further includes a pair of third temperature-sensing resistor elements (Z1,Z2) formed on said second and third substrates (83,85), respectively, and disposed opposite to each other with respect to a third axis perpendicular to said first and second axes in symmetry with said heater (H) so as to detect acceleration in the direction of said third axis.
20. The sensor of claim 18 or 19, wherein each of said first, second and third resistor means pairs is connected with a pair of reference resistors (R01,R02) to form a resistor bridge circuit.
21. The sensor of any preceding claim, wherein said gas (34) has a low heat transfer coefficient.
22. The sensor of any preceding claim, wherein said gas (34) is pressurized.
23. The sensor of any preceding claim, further including an additional substrate (3) mounted on any one of said substrates to close said cavity (4) and form said closed space (8).
24. A method of fabricating an acceleration sensor (1;11;21;31;41;51;61;71;81), comprising the steps of,
  - a) depositing a metal on a semiconductor or insulating substrate (2);
  - b) etching the metal to form a pattern of temperature sensing resistor means (6;13;19;33;52;62); and
  - c) etching the semiconductor or insulating substrate to form a cavity (4) in the substrate (2) and a projection means (5) extending at least part way across the cavity (4), with the pattern of temperature-sensing resistor means deposited on the projection means.
25. The method of claim 24, including, after said etching step c), the step of depositing an oxide layer on said metal pattern of temperature-sensing resistor means.
26. The method of claim 24 or 25, further including the step of mounting a second substrate (3) on the first-mentioned substrate (2) to close the cavity (4).
27. The method of claim 24 or 25, wherein the cavity is formed to extend completely through the substrate and is closed at least at one of its open ends by mounting a second substrate on the first-mentioned substrate.

## Patentansprüche

1. Beschleunigungssensor (1; 11; 21; 31; 41; 51; 61; 71; 81) umfassend wenigstens ein Temperaturfühlerwiderstandsmittel (6; 13; 19; 33; 52; 62), das bei Verwendung in einem geschlossenen Raum (8) angeordnet ist, wobei



- ein Gas (34) in dem geschlossenen Raum (8) erwärmt wird, und wobei sich der Widerstand des Widerstandsmittels aufgrund eines Stroms des Gases (34) über das Widerstandsmittel ändert, wenn eine Beschleunigung auf den Sensor wirkt, dadurch gekennzeichnet, daß der Sensor ein Halbleiter- oder Isoliersubstrat (2) mit einem Hohlraum (4; 43) darin umfaßt sowie einen Vorsprung (5, 15) des Halbleiter- oder Isoliersubstrats, der sich in dem Raum wenigstens teilweise quer zu dem Hohlraum (4) erstreckt, und dadurch, daß das Widerstandsmittel an dem Vorsprung (5) integral ausgebildet ist.
2. Sensor nach Anspruch 1, bei welchem das Widerstandsmittel ein Wärmeterperaturfühlerwiderstandselement (6) ist, das sowohl zum Erwärmen des Gases als auch zum Anzeigen der Beschleunigung durch Verändern des Widerstands verwendet ist.
  3. Sensor nach Anspruch 1 oder 2, bei welchem das Vorsprungsmittel (5) das Zentrum des Hohlraums (4) überbrückt und wobei das Temperaturfühlerwiderstandsmittel (6) im Zentrum des Raums angeordnet ist.
  4. Sensor nach Anspruch 1 ferner umfassend ein Heizmittel (12; 32), das in dem Raum zum Erwärmen des Gases angeordnet ist, wobei das Temperaturfühlerwiderstandsmittel (13; 33) im Abstand zu dem Heizmittel (12; 32) angeordnet ist und wobei das Heizmittel (12; 32) an dem Vorsprungsmittel (5) ausgebildet ist.
  5. Sensor nach Anspruch 4 ferner umfassend ein zweites Temperaturfühlerwiderstandsmittel (14), das gegenüber dem ersten Widerstandsmittel (13) angeordnet ist, wobei das Heizmittel (12) zentral zwischen dem ersten und zweiten Widerstandsmittel (13, 14) angeordnet ist.
  6. Sensor nach Anspruch 5, ferner umfassend eine Erfassungsschaltung zum Erfassen der Veränderung des Widerstands des ersten oder/und zweiten Widerstandsmittels (13, 14), wobei die Erfassungsschaltung eine Brückenschaltung (16) umfaßt, die die ersten und zweiten Widerstandsmittel (13, 14) und erste und zweite Referenzwiderstände (R1, R2) umfaßt, die jeweils damit verbunden sind, um eine Widerstandsbrücke zu bilden, sowie einen Verstärker (18) zum Verstärken der Differenzgangsgröße der Brückenschaltung (16).
  7. Sensor nach Anspruch 1, ferner umfassend ein zweites Temperaturfühlerwiderstandsmittel (20), das gegenüber dem ersten Widerstandsmittel (19) angeordnet ist, wobei die ersten und zweiten Widerstandsmittel (19, 20) beide aus einem Wärmeterperaturfühlerwiderstandselement gebildet sind.
  8. Sensor nach Anspruch 7, bei welchem das Vorsprungsmittel erste und zweite Vorsprünge umfaßt, die sich in den Hohlraum (4) aus gegenüberliegenden Richtungen erstrecken, und wobei die ersten und zweiten Widerstandsmittel (19, 20) an dem ersten bzw. zweiten Vorsprung ausgebildet sind.
  9. Sensor nach Anspruch 4, bei welchem das Heizmittel (32) und das Widerstandsmittel (33) nebeneinander angeordnet sind und in einem vorbestimmten Abstand angeordnet sind.
  10. Sensor nach Anspruch 4 oder 9, ferner umfassend einen Vergleicher (37) zum Vergleichen der Ausgangsgröße des Widerstandsmittels (33) mit einem Referenzwiderstand (Rs), um eine Veränderung des Widerstands des Widerstandsmittels zu bestimmen.
  11. Sensor nach Anspruch 4, 9 oder 10, ferner umfassend ein weiteres Temperaturfühlerwiderstandsmittel (42) zum Erfassen von Umgebungstemperatur und ein Beschleunigungskorrekturmittel (46; 46') zum Korrigieren der Ausgangsgröße von dem ersten Widerstandsmittel (33) auf Basis der Umgebungstemperatur, die von dem weiteren Widerstandsmittel (42) erfaßt ist.
  12. Sensor nach Anspruch 11, bei welchem das Halbleiter- oder Isoliersubstrat ferner einen zweiten Hohlraum (44) umfaßt, der von dem ersterwähnten Hohlraum (43) getrennt ist und mit Umgebungsluft gefüllt ist, wobei das weitere Widerstandsmittel (42) in dem zweiten Hohlraum (44) angeordnet ist und an einem zweiten Vorsprungsmittel des Isoliermaterials ausgebildet ist, das sich in dem zweiten Hohlraum (44) erstreckt.
  13. Sensor nach Anspruch 11, bei welchem das weitere Widerstandsmittel (42) außerhalb des Halbleiter- oder Isoliersubstrats (2) angeordnet ist und an dem Halbleiter- oder Isoliersubstrat angebracht ist.
  14. Sensor nach Anspruch 1, ferner umfassend ein zweites Temperaturfühlerwiderstandsmittel (53; 63; 73), das in dem Raum angeordnet ist und von dem ersten Widerstandsmittel (52; 62; 72) mit einem vorbestimmten Abstand

getrennt angeordnet ist, wobei die ersten und zweiten Widerstandsmittel beide von einem Wärmtemperaturfühlerwiderstandselement gebildet sind und mit ersten bzw. zweiten Referenzwiderständen ( $r_1$ ,  $r_2$ ) verbunden sind, um eine Brückenschaltung (56) zu bilden.

- 5 15. Sensor nach Anspruch 14, bei welchem die ersten und zweiten Referenzwiderstände ( $r_1$ ,  $r_2$ ) außerhalb des Halbleiter- oder Isoliersubstrats angeordnet sind.
16. Sensor nach Anspruch 14 oder 15, ferner umfassend eine Mehrzahl von Heizelementen (64), die an beiden Seiten oder jedem der ersten und zweiten Temperaturfühlerwiderstandsmittel (62, 63) angeordnet sind.
- 10 17. Sensor nach Anspruch 14, bei welchem die ersten und zweiten Referenzwiderstände ( $r_1$ ,  $r_2$ ) in dem Raum angeordnet sind und von dritten und vierten Wärmtemperaturfühlerwiderstandsmitteln (74, 75) gebildet sind.
18. Sensor nach Anspruch 1, ferner umfassend ein Heizelement (H), das in dem Raum zum Erwärmen des Gases darin angeordnet ist, wobei das Widerstandsmittel ein Paar erster Temperaturfühlerwiderstandselemente ( $X_1$ ,  $X_2$ ) umfaßt, die bezüglich einer ersten Achse symmetrisch zu dem Heizelement (H) einander gegenüberliegend angeordnet sind, um eine Beschleunigung in Richtung der ersten Achse zu erfassen, sowie ein Paar zweiter Temperaturfühlerwiderstandselemente ( $Y_1$ ,  $Y_2$ ), die bezüglich einer zweiten Achse orthogonal zu der ersten Achse symmetrisch zu dem Heizelement (H) einander gegenüberliegend angeordnet sind, um eine Beschleunigung in Richtung der zweiten Achse zu erfassen.
- 15 19. Sensor nach Anspruch 18, ferner umfassend zweite und dritte Halbleiter- oder Isoliersubstrate (83, 85), die an entgegengesetzten Flächen des ersterwähnten Substrats (84) angebracht sind und jeweils einen Hohlraum (86, 89) darin aufweisen, der mit dem Hohlraum (88) in dem ersterwähnten Substrat (84) in Verbindung ist, wobei das Widerstandsmittel ferner ein Paar dritter Temperaturfühlerwiderstandselemente ( $Z_1$ ,  $Z_2$ ) umfaßt, die an dem zweiten bzw. dritten Substrat (83, 85) angeordnet sind und bezüglich einer dritten Achse orthogonal zu den ersten und zweiten Achsen symmetrisch zu dem Heizelement (H) einander gegenüberliegend angeordnet sind, um eine Beschleunigung in Richtung der dritten Achse zu erfassen.
- 20 20. Sensor nach Anspruch 18 oder 19, bei welchem jedes der ersten, zweiten und dritten Widerstandsmittel Paare mit einem Paar Referenzwiderständen ( $R_{01}$ ,  $R_{02}$ ) verbunden ist, um eine Widerstandsbrückenschaltung zu bilden.
- 25 21. Sensor nach einem der vorhergehenden Ansprüche, bei welchem das Gas (34) einen niedrigen Wärmeübergangskoeffizienten aufweist.
- 30 22. Sensor nach einem der vorhergehenden Ansprüche, bei welchem das Gas (34) unter Druck gesetzt ist.
23. Sensor nach einem der vorhergehenden Ansprüche, ferner umfassend ein zusätzliches Substrat (3), das an irgendeinem der Substrate angebracht ist, um den Hohlraum (4) zu schließen und den geschlossenen Raum (8) zu bilden.
- 40 24. Verfahren zum Herstellen eines Beschleunigungssensors (1; 11; 21; 31; 41; 51; 61; 71, 81), umfassend die Schritte:
  - a) Ablagern eines Metalls an ein Halbleiter- oder Isoliersubstrat (2);
  - 45 b) Ätzen des Metalls, um ein Muster aus Temperaturfühlerwiderstandsmitteln (6; 13; 19; 33; 52; 62) zu bilden; und
  - c) Ätzen des Halbleiter- oder Isoliersubstrats, um einen Hohlraum (4) in dem Substrat (2) und ein Vorsprungsmittel (5) zu bilden, das sich wenigstens teilweise quer zu dem Hohlraum (4) erstreckt, wobei das Muster der Temperaturfühlerwiderstandsmittel an dem Vorsprungsmittel abgelagert ist.
- 50 25. Verfahren nach Anspruch 24, umfassend: nach dem Ätzschritt c) den Schritt des Ablagerns einer Oxidschicht auf das Metallmuster der Temperaturfühlerwiderstandsmittel.
26. Verfahren nach Anspruch 24 oder 25, ferner umfassend den Schritt: Anbringen eines zweiten Substrats (3) an dem ersterwähnten Substrat (2), um den Hohlraum (4) zu schließen.
- 55 27. Verfahren nach Anspruch 24 oder 25, bei welchem der Hohlraum derart gebildet ist, daß er sich vollständig durch das Substrat erstreckt, und wenigstens an einem seiner offenen Enden durch Anbringen eines zweiten Substrats

an dem ersterwähnten Substrat geschlossen wird.

## Revendications

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1. Capteur d'accélération (1 ; 11 ; 21 ; 31 ; 41 ; 51 ; 61 ; 71 ; 81) comportant au moins un moyen formant résistance de détection de température (6 ; 13 ; 19 ; 33 ; 52 ; 62) disposé, en utilisation, dans un espace fermé (8), du gaz (34) situé dans ledit espace fermé (8) étant chauffé, et dans lequel la résistance desdits moyens formant résistance change lorsqu'une accélération agit sur ledit capteur du fait de l'écoulement dudit gaz (34) sur lesdits moyens formant résistance, caractérisé en ce que ledit capteur comporte un substrat semi-conducteur ou isolant (2) ayant une cavité (4 ; 43) agencée dans celui-ci, et une saillie (5, 15) du substrat semi-conducteur ou isolant s'étendant dans l'espace, d'une manière au moins partielle, à travers ladite cavité (4), et en ce que lesdits moyens formant résistance sont formés en un seul bloc sur ladite saillie (5).
2. Capteur selon la revendication 1, dans lequel lesdits moyens formant résistance sont un élément (6) formant résistance de détection de température du type thermique qui est utilisé à la fois pour chauffer ledit gaz et indiquer l'accélération en changeant la résistance.
3. Capteur selon la revendication 1 ou 2, dans lequel lesdits moyens (5) formant saillie forment un pont au centre de ladite cavité (4), et lesdits moyens formant résistance de détection de température (6) sont disposés au centre dudit espace.
4. Capteur selon la revendication 1, comportant de plus des moyens de chauffage (12 ; 32) disposés dans ledit espace pour chauffer le gaz, dans lequel lesdits moyens formant résistance de détection de température (13 ; 33) sont espacés desdits moyens de chauffage (12 ; 32), et lesdits moyens de chauffage (12 ; 32) sont formés sur lesdits moyens formant saillie (5).
5. Capteur selon la revendication 4, comportant de plus des seconds moyens formant résistance de détection de température (14) disposés opposés auxdits premiers moyens formant résistance (13), lesdits moyens de chauffage (12) étant disposés centralement entre lesdits premiers et seconds moyens formant résistance (13, 14).
6. Capteur selon la revendication 5, comportant de plus un circuit de détection pour détecter le changement de résistance d'un ou des deux parmi lesdits premiers et seconds moyens formant résistance (13, 14), ledit circuit de détection comportant un circuit en pont (16) incluant lesdits premiers et seconds moyens formant résistance (13, 14) et des première et seconde résistances de référence (R1, R2) reliées respectivement à celles-ci pour former un pont de résistances, et un amplificateur (18) pour amplifier la sortie différentielle dudit circuit en pont (16).
7. Capteur selon la revendication 1, comportant de plus des seconds moyens formant résistance de détection de température (20) disposés opposés auxdits premiers moyens formant résistance (19), dans lequel lesdits premiers et seconds moyens formant résistance (19, 20) sont tous deux formés d'un élément formant résistance de détection de température du type thermique.
8. Capteur selon la revendication 7, dans lequel lesdits moyens formant saillie comportent des première et seconde saillies s'étendant à l'intérieur de ladite cavité (4) à partir de directions opposées, et lesdits premiers et seconds moyens formant résistance (19, 20) sont formés sur lesdites première et seconde saillies respectivement.
9. Capteur selon la revendication 4, dans lequel lesdits moyens de chauffage (32) et lesdits moyens formant résistance (33) sont disposés côte à côte et espacés d'une distance prédéterminée.
10. Capteur selon la revendication 4 ou 9, comportant de plus un comparateur (37) pour comparer la sortie desdits moyens formant résistance (33) à une résistance de référence (Rs) pour déterminer un changement de résistance desdits moyens formant résistance.
11. Capteur selon la revendication 4, 9 ou 10, comportant de plus d'autres moyens formant résistance de détection de température (42) pour détecter la température ambiante, et des moyens de correction d'accélération (46 ; 46') pour corriger la sortie desdits premiers moyens formant résistance (33) sur la base de la température ambiante détectée par lesdits autres moyens formant résistance (42).

12. Capteur selon la revendication 11, dans lequel ledit substrat semi-conducteur ou isolant comporte de plus une seconde cavité (44) séparée de ladite première cavité citée (43) et remplie d'air ambiant, lesdits autres moyens formant résistance (42) étant disposés dans ladite seconde cavité (44) et formés sur des seconds moyens formant saillie constitués d'un matériau isolant s'étendant dans ladite seconde cavité (44).
13. Capteur selon la revendication 11, dans lequel lesdits autres moyens formant résistance (42) sont disposés à l'extérieur dudit substrat semi-conducteur ou isolant (2) et reliés audit substrat semi-conducteur ou isolant.
14. Capteur selon la revendication 1, comportant de plus des seconds moyens formant résistance de détection de température (53 ; 63 ; 73) disposés dans ledit espace et séparés desdits premiers moyens formant résistance (52 ; 62 ; 72) d'une distance prédéterminée, dans lequel lesdits premiers et seconds moyens formant résistance sont tous deux formés d'un élément formant résistance de détection de température du type thermique et reliés auxdites première et seconde résistances de référence (r1, r2), respectivement, pour former un circuit en pont (56).
15. Capteur selon la revendication 14, dans lequel lesdites première et seconde résistances de référence (r1, r2) sont disposées à l'extérieur dudit substrat semi-conducteur ou isolant.
16. Capteur selon la revendication 14 ou 15, comportant de plus une pluralité de dispositifs de chauffage (64) disposés des deux côtés de chacun desdits premiers et seconds moyens formant résistance de détection de température (62, 63).
17. Capteur selon la revendication 14, dans lequel lesdites première et seconde résistances de référence (r1, r2) sont disposées dans ledit espace et formées par des troisièmes et quatrièmes moyens formant résistance de détection de température du type thermique (74, 75).
18. Capteur selon la revendication 1, comportant de plus un dispositif de chauffage (H) disposé dans ledit espace pour chauffer le gaz existant dans celui-ci, dans lequel lesdits moyens formant résistance comportent une paire de premiers éléments formant résistance de détection de température (X1, X2) disposés de manière opposée l'un à l'autre par rapport à un premier axe, symétriquement par rapport au dispositif de chauffage (H), de manière à détecter l'accélération dans la direction dudit premier axe, et une paire de deuxièmes éléments formant résistance de détection de température (Y1, Y2) disposés de manière opposée l'un à l'autre par rapport à un second axe perpendiculaire audit premier axe, symétriquement par rapport au dispositif de chauffage (H), de manière à détecter une accélération dans la direction dudit second axe.
19. Capteur selon la revendication 18, comportant de plus des deuxième et troisième substrats semi-conducteurs ou isolants (83, 85) montés sur des surfaces opposées dudit premier substrat cité (84) et ayant chacun une cavité (86, 89) agencée dans celui-ci communiquant avec la cavité (88) dudit premier substrat cité (84), dans lequel lesdits moyens formant résistance comportent de plus une paire de troisièmes éléments formant résistance de détection de température (Z1, Z2) formés sur lesdits deuxième et troisième substrats (83, 85), respectivement, et disposés opposés l'un par rapport à l'autre par rapport à un troisième axe perpendiculaire aux premier et deuxième axes, symétriquement par rapport audit dispositif de chauffage (H), de manière à détecter une accélération dans la direction dudit troisième axe.
20. Capteur selon la revendication 18 ou 19, dans lequel chacune desdites première, deuxième et troisième paires de moyens formant résistance est reliée à une paire de résistances de référence (RO1, RO2) pour former un circuit en pont à résistances.
21. Capteur selon l'une quelconque des revendications précédentes, dans lequel ledit gaz (34) a un faible coefficient de transfert thermique.
22. Capteur selon l'une quelconque des revendications précédentes, dans lequel ledit gaz (34) est sous pression.
23. Capteur selon l'une quelconque des revendications précédentes, comportant de plus un substrat supplémentaire (3) monté sur l'un quelconque desdits substrats pour fermer ladite cavité (4) et former ledit espace fermé (8).
24. Procédé de fabrication d'un capteur d'accélération (1 ; 11 ; 21 ; 31 ; 41 ; 51 ; 61 ; 71 ; 81) comportant les étapes consistant à :

- a) déposer un métal sur un substrat semi-conducteur ou isolant (2),  
b) graver le métal pour former un motif de moyens formant résistance de détection de température (6 ; 13 ; 19 ; 33 ; 52 ; 62), et  
c) graver le substrat semi-conducteur ou isolant pour former une cavité (4) dans le substrat (2) et des moyens formant saillie (5) s'étendant au moins partiellement à travers la cavité (4), le motif des moyens formant résistance de détection de température étant déposé sur les moyens formant saillie.

25. Procédé selon la revendication 24, comportant, après ladite étape c) de gravure, l'étape consistant à déposer une couche d'oxyde sur ledit motif de métal des moyens formant résistance de détection de température.

26. Procédé selon la revendication 24 ou 25, comportant de plus l'étape consistant à monter un second substrat (3) sur le premier substrat cité (2) pour fermer la cavité (4).

27. Procédé selon la revendication 24 ou 25, dans lequel la cavité est formée pour s'étendre entièrement à travers le substrat et est fermée au moins à une première des extrémités ouvertes en montant un second substrat sur le premier substrat cité.

Fig. 1

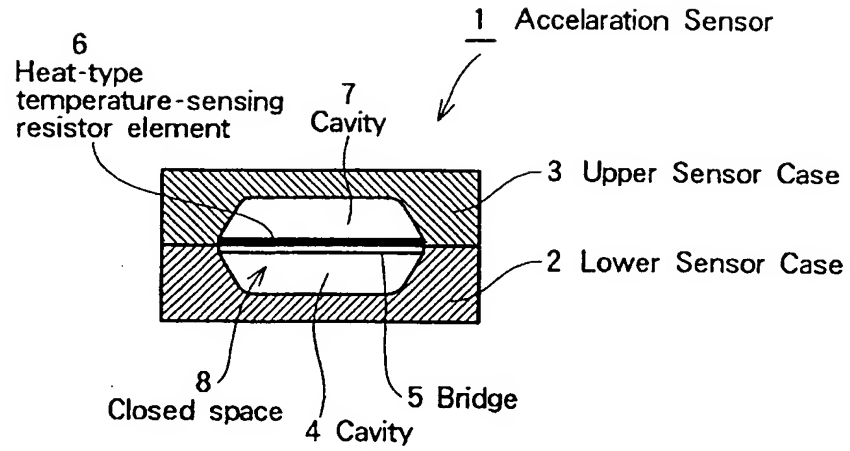


Fig. 2

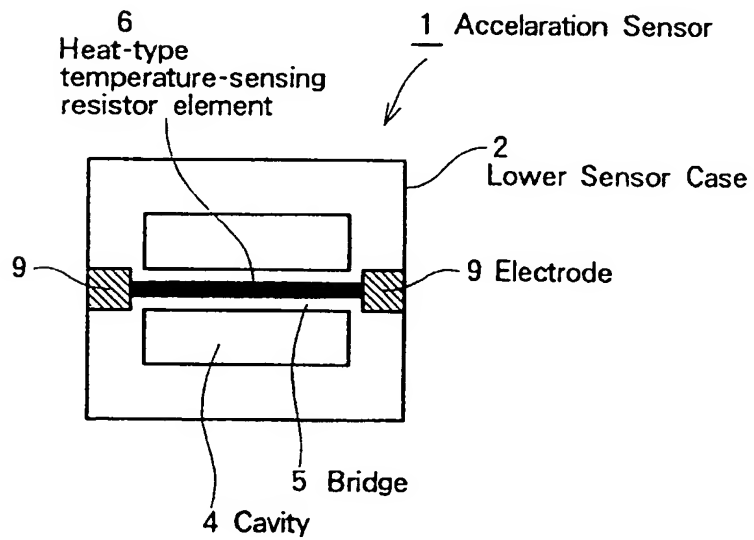


Fig. 3

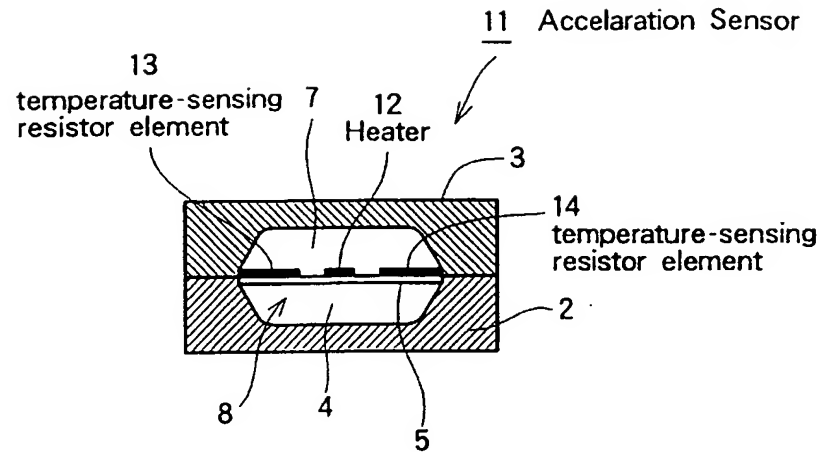


Fig. 4

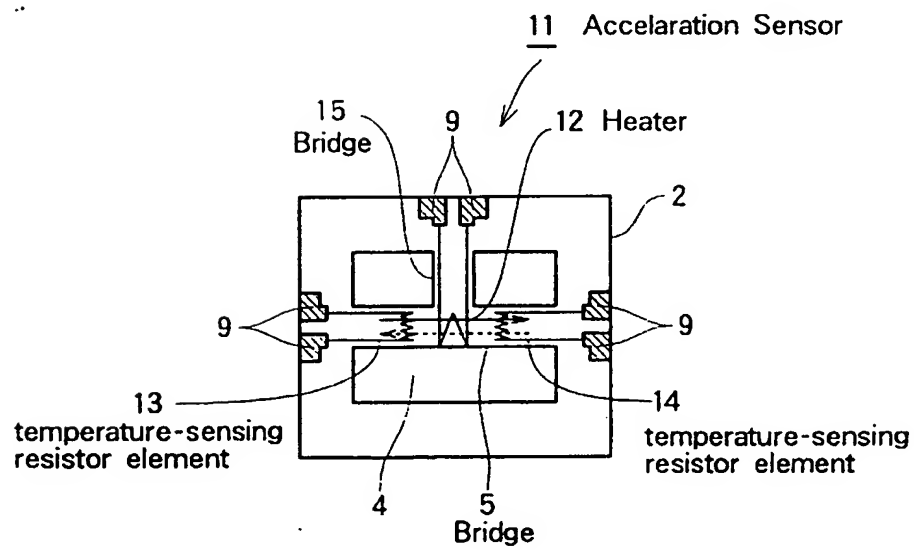


Fig. 5

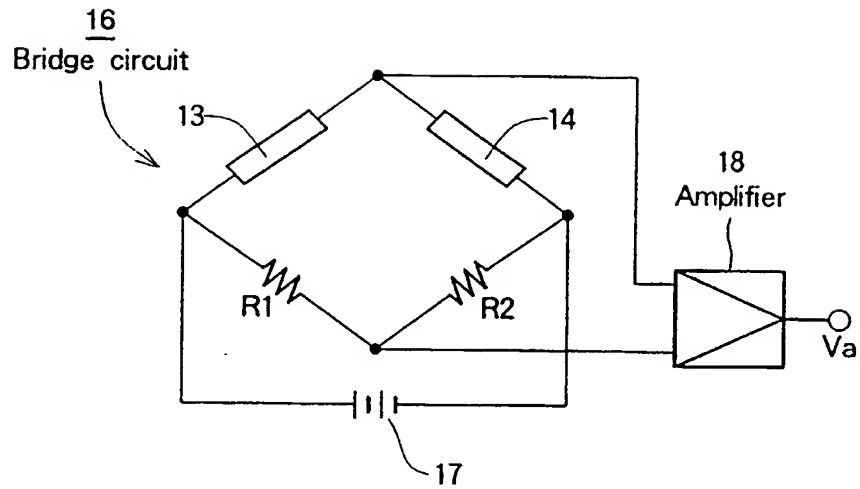


Fig. 6

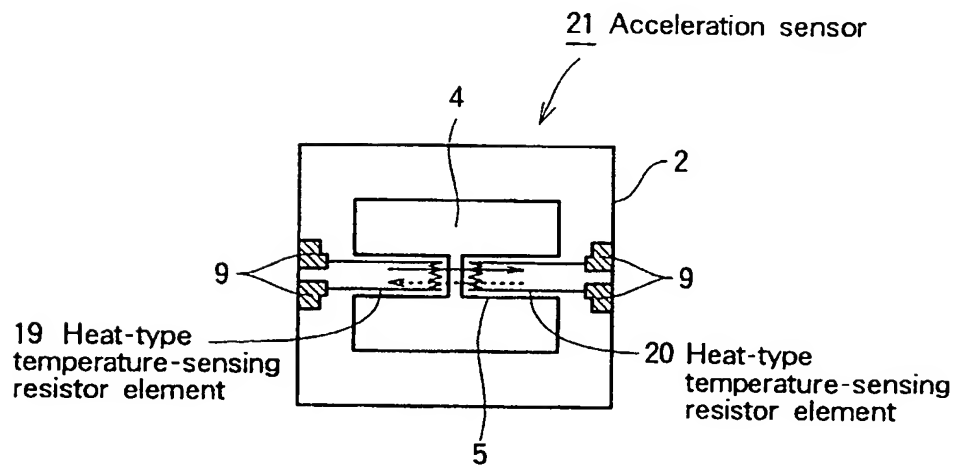




Fig. 7

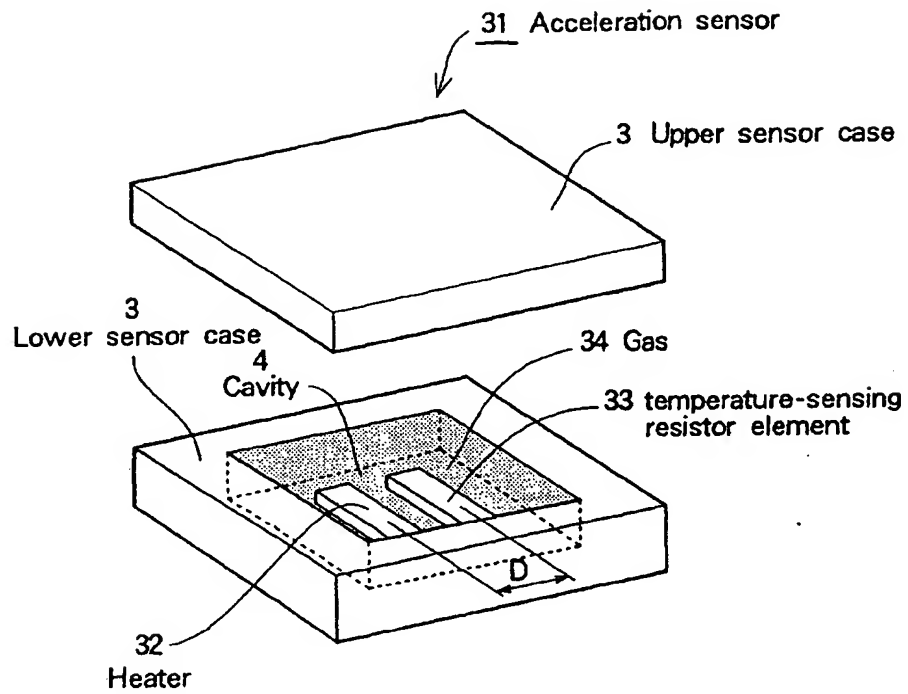


Fig. 8

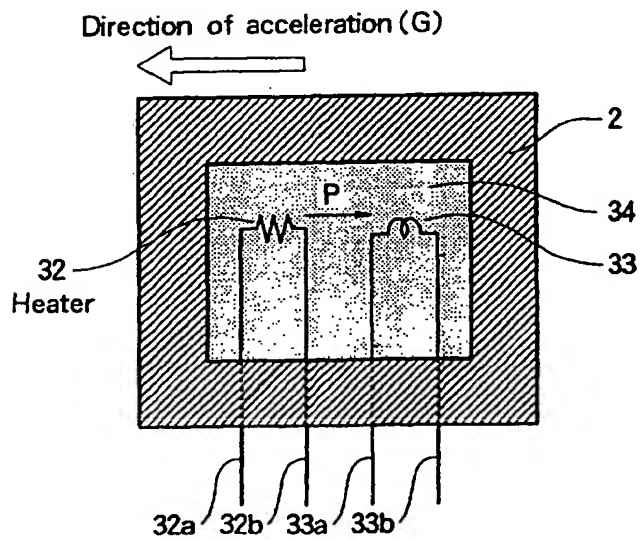


Fig. 9

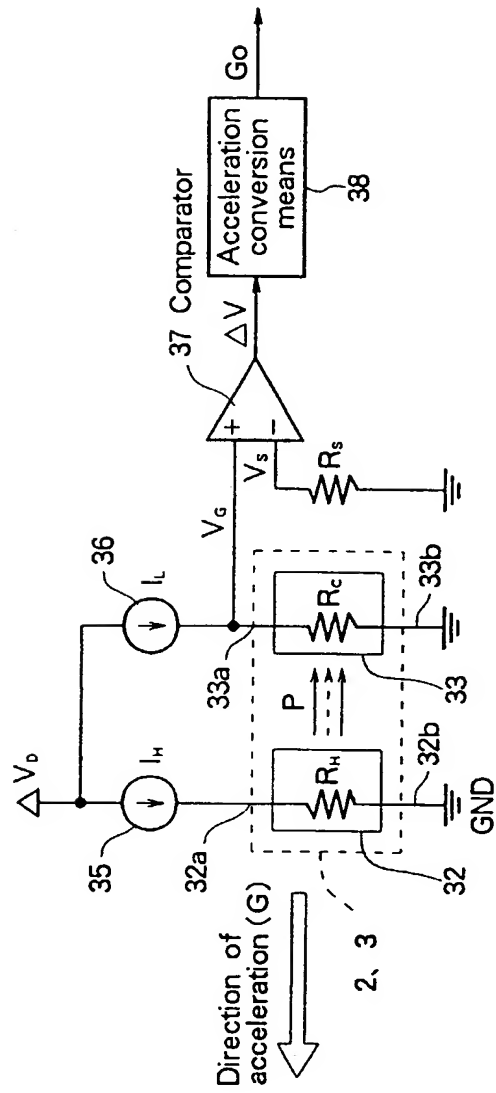


Fig. 10

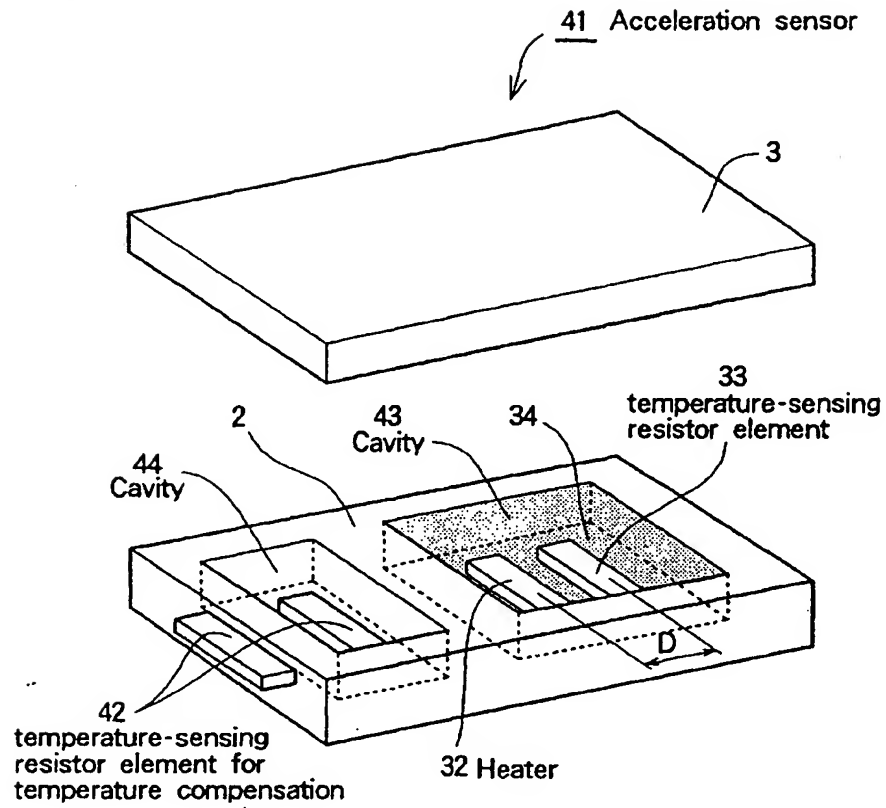


Fig. 11

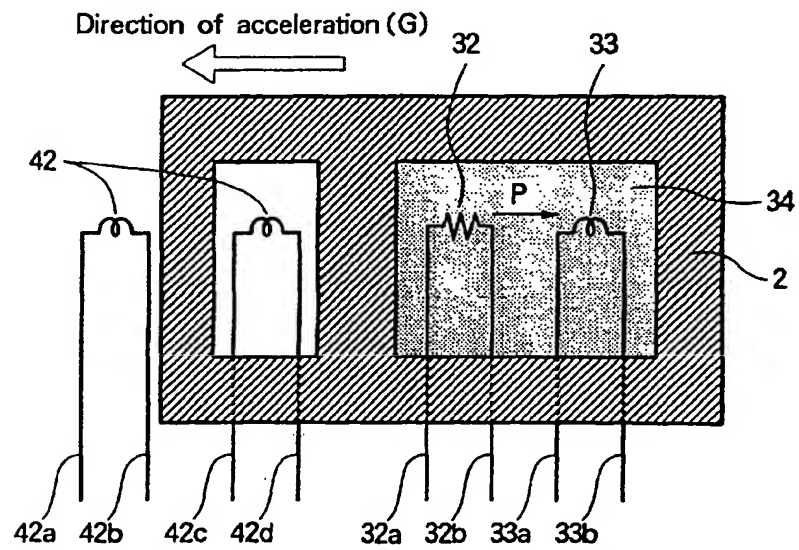


Fig. 12

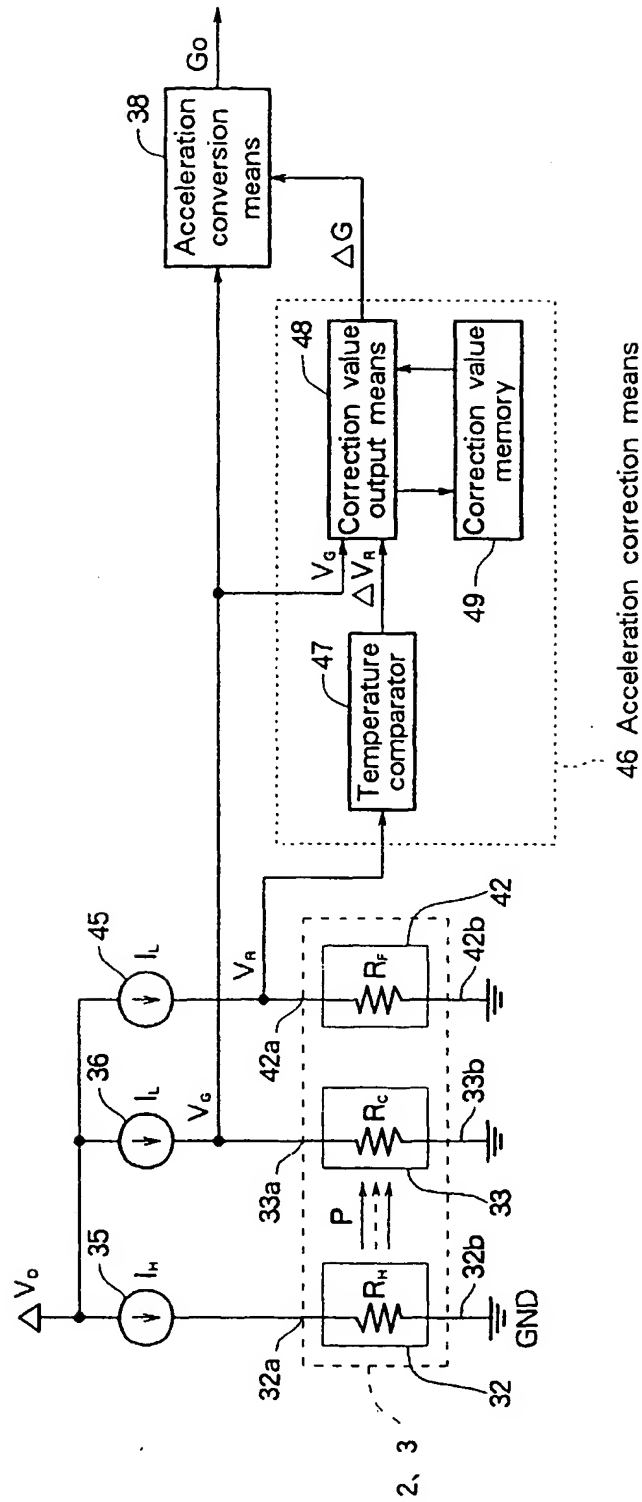


Fig. 13

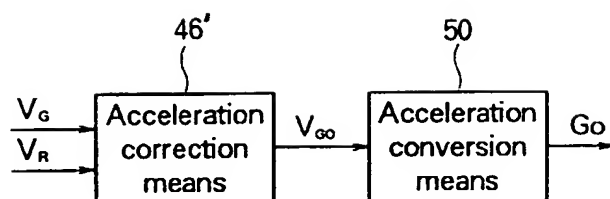


Fig. 14

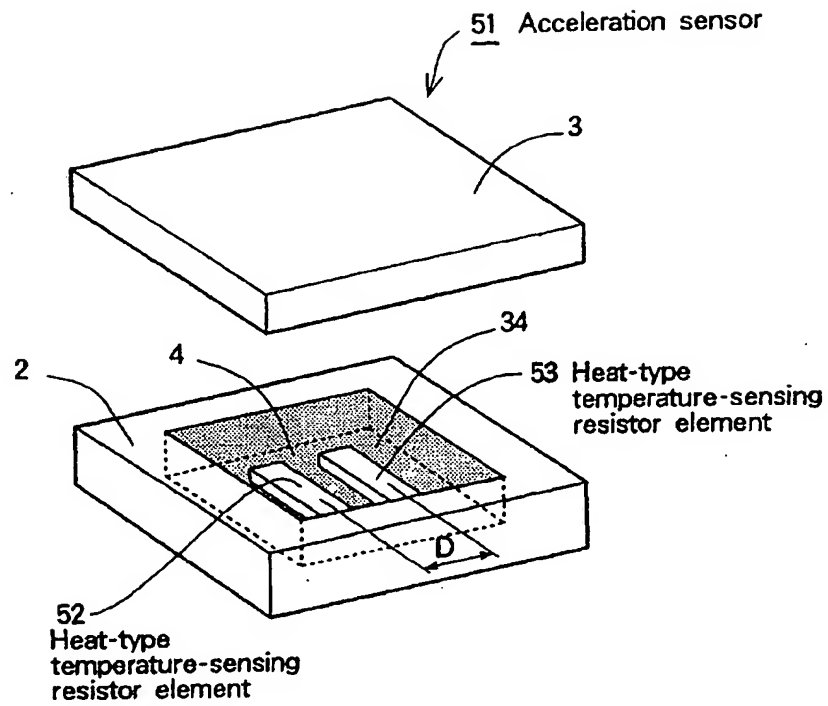


Fig. 15

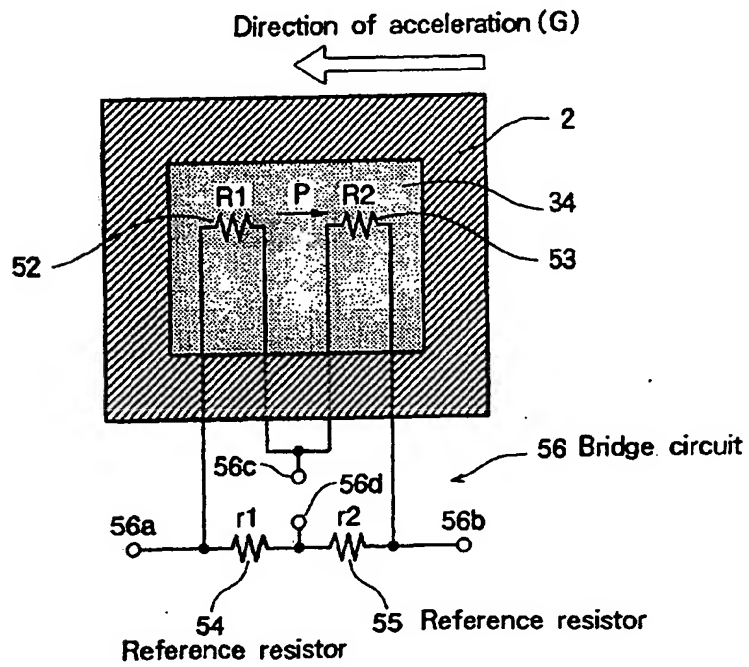


Fig. 16

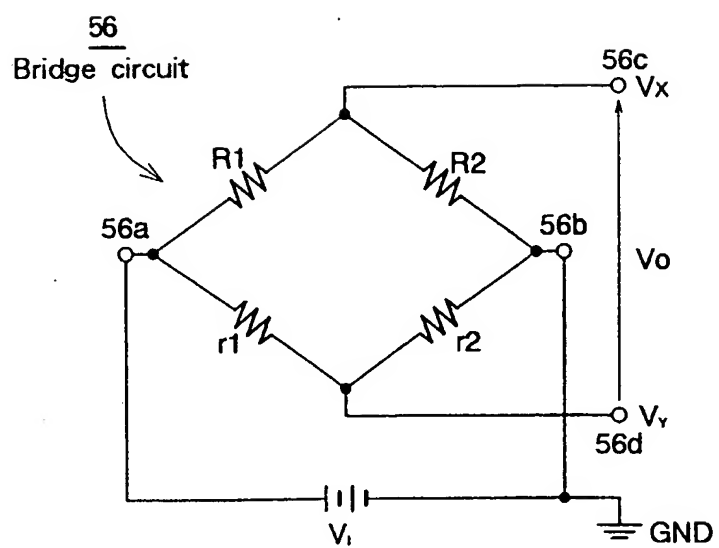


Fig.17

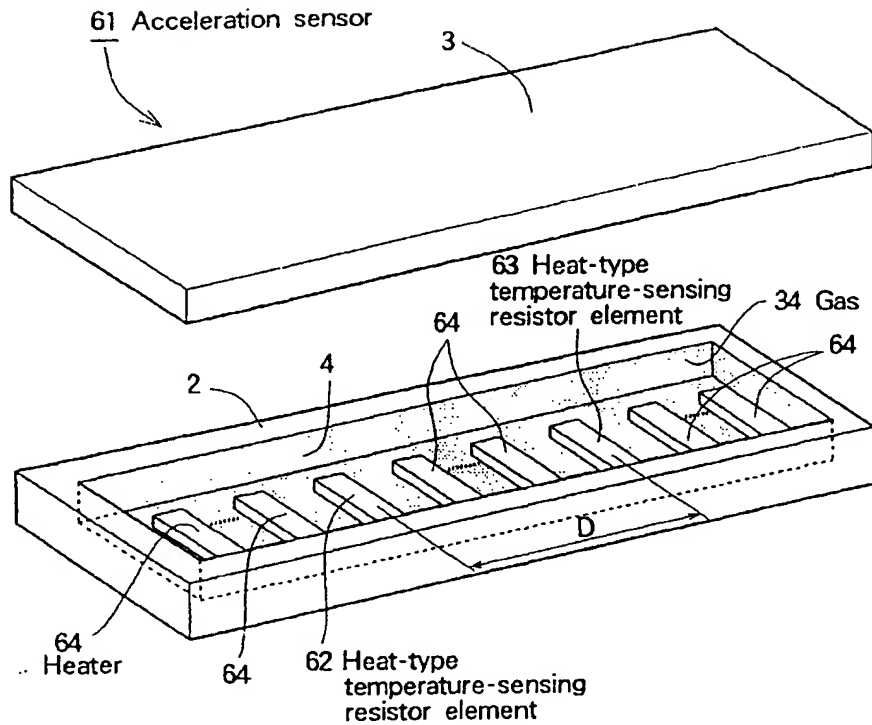


Fig.18

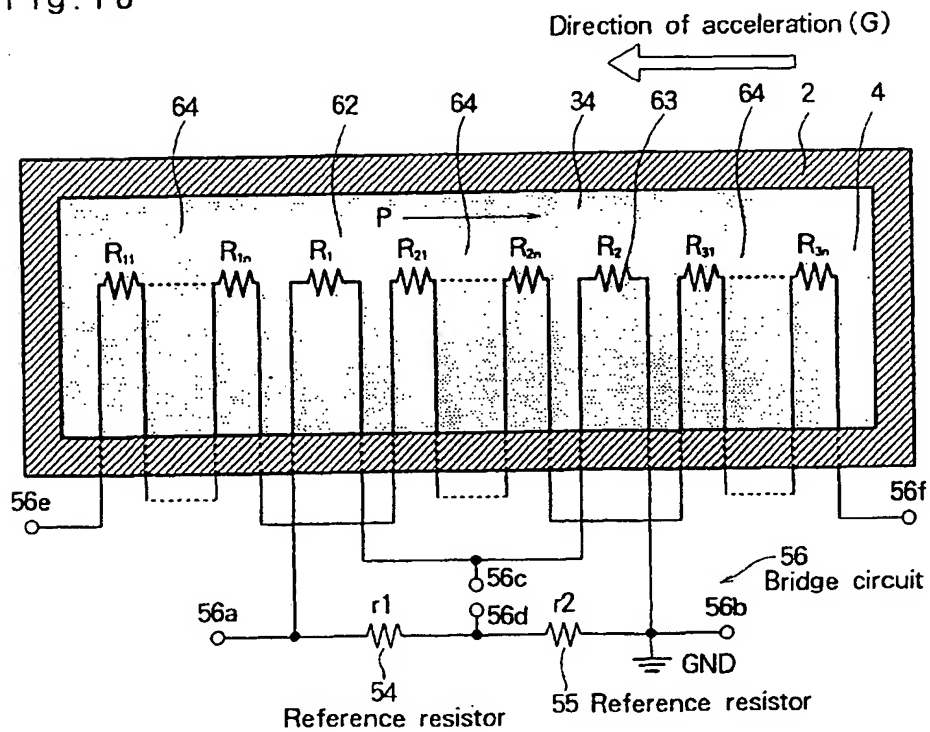




Fig.19

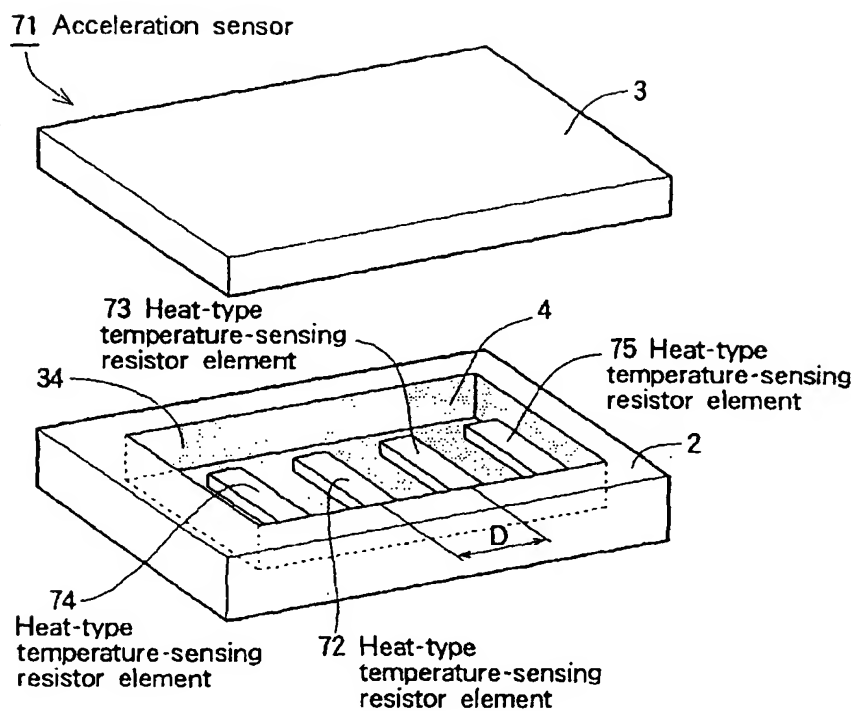


Fig.20

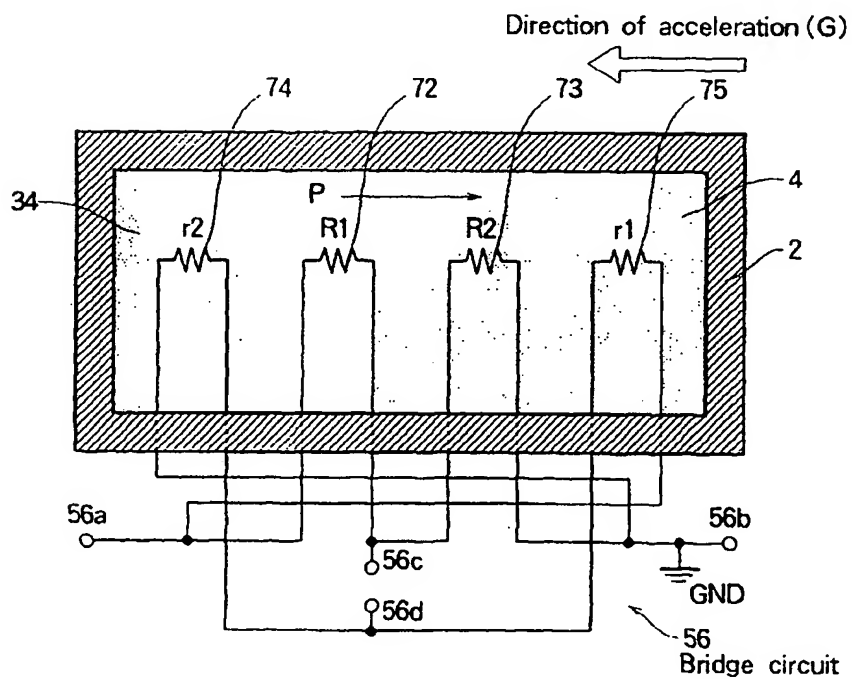


Fig.21

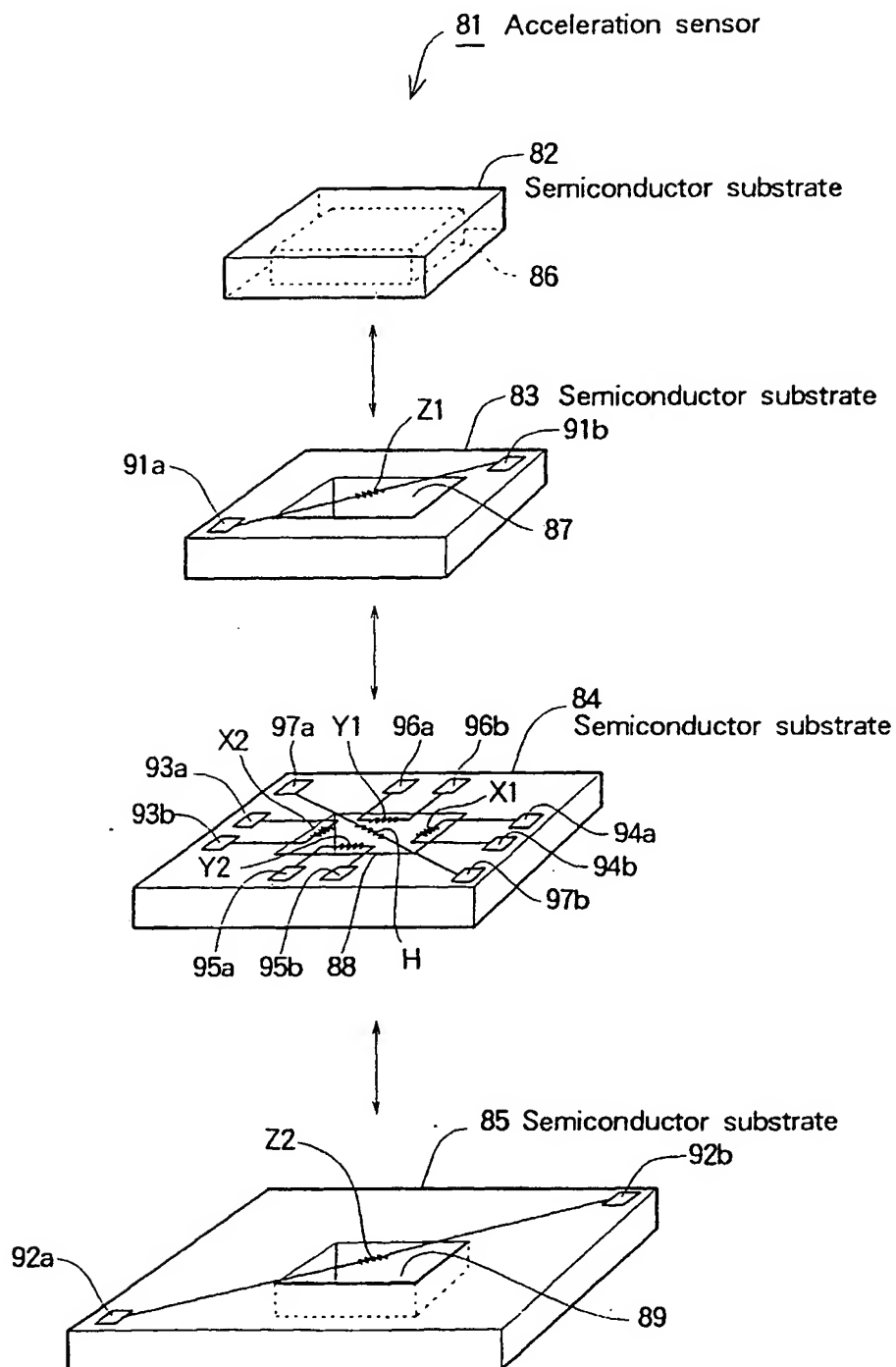


Fig.22a

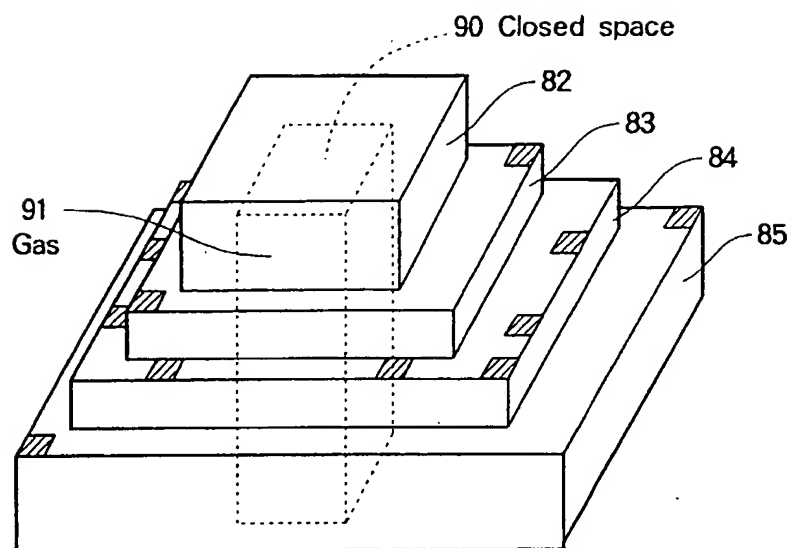


Fig.22b

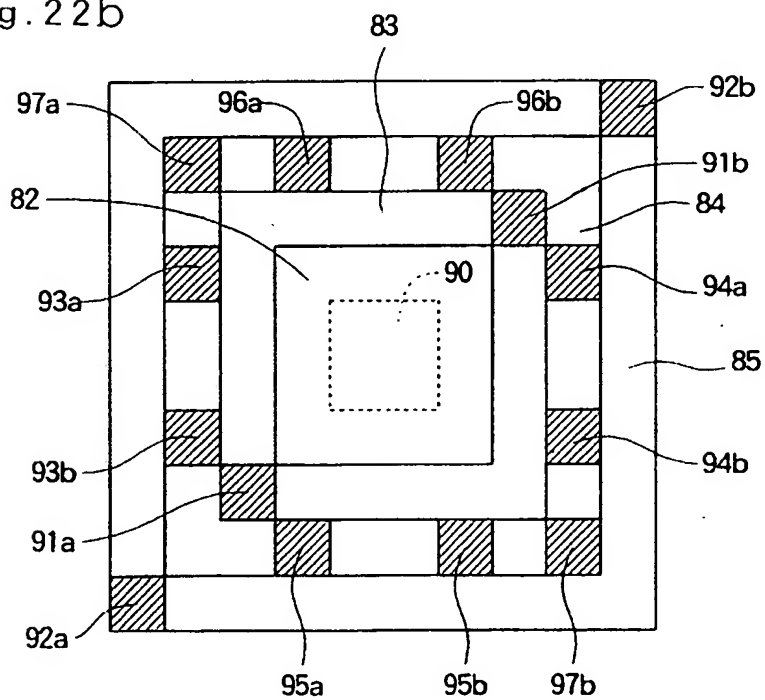


Fig. 23

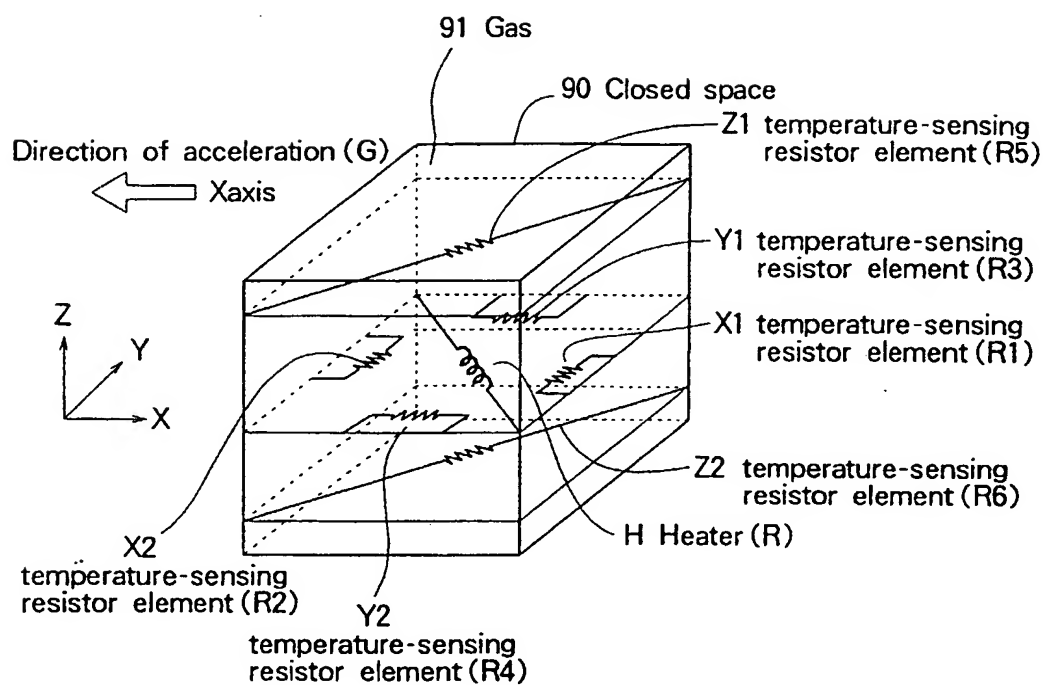


Fig.24

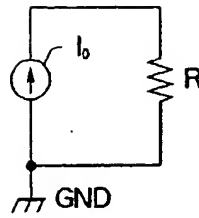


Fig.25

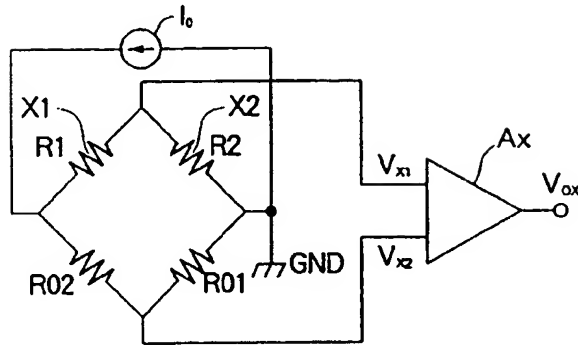


Fig.26

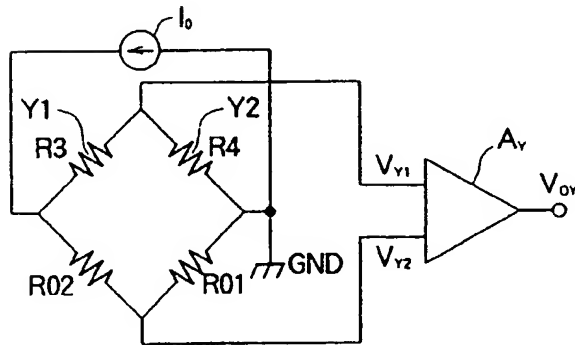


Fig.27

